Survey report for the Los Angeles river watershed 1941

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SURVEY REPORT FOR THE LOS ANGELES RIVER WATERSHED

LETTER

FROM THE

UNDER SECRETARY OF AGRICULTURE

TRANSMITTING

A COPY OF A SURVEY REPORT FOR THE LOS ANGELES RIVER WATERSHED

NOVEMBER 3, 1941.—Referred to the Committee on Flood Control and ordered to be printed, with illustration

UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1941

LETTER OF SUBMITTAL

DEPARTMENT OF AGRICULTURE,
Washington, October 23, 1941.

Hon. SAM RAYBURN,
Speaker of the House of Representatives.

DEAR MR. RAYBURN: There is enclosed a copy of a survey report for the Los Angeles River watershed, which has been prepared and is submitted to the Congress by the Department of Agriculture in accordance with the provisions of section 6 of the Flood Control Act approved June 22, 1936. This report outlines a plan of action for this watershed in order to cope with problems of "run-off and waterflow retardation and soil-erosion prevention" in aid of flood control.

The plans contained in this report have been approved by this office. In our estimation a watershed improvement program for the Los Angeles River drainage is deserving of first priority among various such projects in the United States. The rapid growth of population and the continued encroachment upon the flood plains are creating hazards to life and to property. Enormous damages have been caused by severe debris flows and floods, many of which originate on the public lands under the jurisdiction of the Department. The damages to agricultural, urban, and suburban property from debris and silt originating on mountain and agricultural lands and from the shifting of stream channels choked by this debris are extreme and especially so when flood-producing storms follow forest fires on the mountain slopes. These damages, together with large Federal and local investment in flood-control structures whose useful life span will be lengthened by the reduction in debris movement, as well as the favorable cost benefit ratio determined for our program, indicate that the watershed stands very high among those most in need of upstream protection.

National-defense interests are strongly involved. Aircraft factories and the homes of workmen engaged on national-defense orders lie within the area to be protected. Vital highways, railroads, power lines, and communication lines also traverse the valley lands, and damages to any of these, comparable to those experienced in the past, would slow up production of needed defense material.

The program proposed divides itself into two parts, that on the rough and broken mountain lands and that on the sloping agricultural lands below. It includes the application of various upstream engineering devices such as stream barriers, terraces, etc., and the intensification and extension of protective measures—fire control, revegetation, etc.—as a means of reducing the enormous volume of debris which is washed down into the densely settled portions of the watershed.

The upstream program for the Los Angeles River watershed calls for an expenditure of approximately $11,500,000 for complete in-

stallation. The Federal Government of course is to meet the cost of all works on Federal lands. On private and non-Federal public lands, local agencies and private individuals will meet approximately 50 percent of the costs. In addition, easements, rights-of-way, etc., are to be provided by local agencies. The total installation costs on both private and public land to the Federal Government will amount to $8,500,000.

The annual maintenance cost will approximate $537,000. About $229,000 a year will be paid by State and local governments and by farmers and other individuals. The balance of $308,000 will have to be provided out of Federal funds.

The figures in the report which show the distribution of the $8,500,000 Federal contribution among the various types of work are regarded as approximations only and may have to be adjusted as the work progresses, but the total installation costs of all the work to the Federal Government will not exceed $8,500,000. Similarly, the break-down of the total estimate on maintenance may require adjustment from time to time.

The benefits resulting from this program over a 50-year period will be $1.85 for each $1 of cost.

The plan proposed by the Department has been integrated with that of the Corps of Engineers and local agencies with whom the Department has been in touch since the initiation of the investigation. There are no reclamation features or power developments involved in this program.

The Department of Agriculture has negotiated a memorandum of understanding with the local agencies directly concerned in the carrying out of the remedial program. A copy of this memorandum, approved January 22, 1941, is attached to the report.

One million four hundred ten thousand dollars of the $4,000,000 appropriated for work by this Department in the War Department Civil Appropriation Act, 1939, has been allotted for work on this watershed. This amount will make possible completion of the work now actively under way on the Arroyo Seco and San Fernando Valley segments of this watershed.

Sincerely,

PAUL H. APPLEBY,
Under Secretary.

Enclosure.

U. S. DEPARTMENT OF AGRICULTURE

PROGRAM FOR RUN-OFF AND WATER-FLOW RETARDATION
AND SOIL EROSION PREVENTION IN AID
OF FLOOD CONTROL

LOS ANGELES RIVER WATERSHED

In Compliance with
Section 6 of the Flood Control Act of June 22, 1936
Public No. 738, 74th Congress

PROGRAM FOR RUN-OFF AND WATER-FLOW RETARDATION AND SOIL-EROSION PREVENTION IN AID OF FLOOD CONTROL

MEMORANDUM OF UNDERSTANDING BETWEEN THE SECRETARY OF AGRICULTURE OF THE UNITED STATES AND THE COUNTY OF LOS ANGELES, THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT, THE CITY OF LOS ANGELES, THE CITY OF GLENDALE, THE COUNTY OF VENTURA, AND THE STATE OF CALIFORNIA, DEPARTMENT OF PUBLIC WORKS, DIVISION OF HIGHWAYS

STATEMENT OF PURPOSE

It is the purpose of this memorandum to establish a basis upon which the parties hereto may cooperate in a program of watershed improvement in aid of flood control on the watershed of the Los Angeles River in California.

The Secretary of Agriculture of the United States is authorized by the Flood Control Act of June 22, 1936 (49 Stat. 1570), and the War Department Civil Appropriation Act, 1939 (52 Stat. 667), to prosecute works of improvement for measures of run-off and water-flow retardation and soil-erosion prevention in aid of flood control, on the watershed of the Los Angeles River in California, in accordance with plans approved by him. In prosecuting such works of improvement, the Secretary of Agriculture is authorized to cooperate with State and local agencies such as those above named. The survey report, Los Angeles River watershed, hereinafter referred to as the plan and designated as exhibit A, a copy of which is attached, has been approved by the Secretary of Agriculture, as provided by law.

In accordance with the plan, the flood-control measures recommended for installation and the amount of Federal flood-control funds estimated for each are as follows:

1. Fire control, including construction and improvement of fire-truck roads, crew stations, firebreaks and communication lines, and the purchase of tank trucks and other necessary supplies	$3, 197, 751
2. Cover improvement, including direct seeding in bare areas, areas of depleted cover, and recently burned areas	74, 420
3. Road improvement, including improved drainage and slope stabilization by engineering works and planting	796, 844
4. Mountain channel improvement, including the construction of barriers, revetments and deflectors, channel clearing, and occasional channel changes	2, 868, 555
5. Farm land improvement and treatment, including terracing, contour plowing, basin listing, improvement of irrigation practices, crop rotation, planting cover crops, grazing control, pasture improvement, vegetative treatment of small channels, and small check dams for gully control	1, 054, 060
6. Debris basins and improvement of minor channels	388, 005
Total	8, 379, 635

The plan provides that the State and local governments participating in the program will contribute approximately $1,884,775 for the installation of flood-control measures on non-Federal lands, and that farmers and other persons will contribute approximately $1,151,759 in the form of labor, materials, and equipment for the installation of recommended measures on privately owned lands. The estimated cost of installation of the recommended measures to each of the parties hereto is shown in a table of installation costs, marked exhibit B, which is hereto attached.

It is estimated that the average annual cost of operation, maintenance, and replacement of structures and measures will be approximately $536,971, of which the Secretary of Agriculture will provide approximately $307,963 and local governmental agencies will provide approximately $50,645. Owners and operators of land are expected to provide approximately $178,363 to maintain and continue the measures of farm land improvement and treatment. The estimated average annual maintenance cost to each of the parties hereto is shown in a table of maintenance costs marked "Exhibit C," which is hereto attached.

It is estimated that the program provided for in the plan will yield benefits in excess of the cost at the rate of $1.87 of benefits for each $1 of cost.

The Secretary of Agriculture now has available the sum of $1,410,000 with which to begin operations, pursuant to the plan. That fund will be used for operations in the Arroyo Seco and San Fernando Valley in cooperation with local agencies. However, before beginning any operations, the parties hereto desire to establish a basis of cooperation for all work contemplated in the plan.

In view of the foregoing considerations, the parties hereto agree to participate in the carrying out of the plan on the following basis:

Part 1

A. FIRE CONTROL

I. Installation of measures.

(1) The Secretary of Agriculture, through the Forest Service of the United States Department of Agriculture, will pay the entire cost of the installation of fire-control measures in aid of flood control on all Federal lands, and one-half the cost of such measures on non-Federal lands, the total estimated fire-control installation cost to the Secretary of Agriculture to be approximately $3,197,751.

(2) The County of Los Angeles will pay one-half the cost of the installation of fire-control measures in aid of flood control on non-Federal lands within the county, plus the cost of certain rights-of-way on lands not owned by the United States within the county, the total estimated cost to the county to be approximately $112,233.

(3) The City of Los Angeles will pay one-half the cost of the installation of fire-control measures in aid of flood control on non-Federal lands within the city, plus the cost of necessary rights-of-way within the city, the total cost to the city to be approximately $140,337.

II. Maintenance, operation, and replacement of measures.

(1) The Secretary of Agriculture, through the Forest Service, will be responsible for maintenance, operation, and replacement of fire-

control measures in aid of flood control on Federal lands, the estimated average annual cost of which will be approximately $298,438.

(2) The County of Los Angeles will be responsible for maintenance, operation, and replacement of fire-control measures in aid of flood control on non-Federal lands within the county, the estimated average annual cost of which will be approximately $30,000.

(3) The City of Los Angeles will be responsible for the maintenance, operation, and replacement of fire-control measures in aid of flood control on non-Federal lands within the city, the estimated average annual cost of which will be approximately $6,000.

B. COVER IMPROVEMENT—FEDERAL LANDS

The Secretary of Agriculture, through the Forest Service, will provide cover improvement in aid of flood control on Federal lands at an estimated cost of $74,420, and will provide necessary replacement of cover following fires at an estimated average annual cost of $450.

C. ROAD IMPROVEMENT

I. Installation of measures.

(1) The Secretary of Agriculture, through the Forest Service, will pay the entire cost of installation of road improvement work in aid of flood control on all Federal lands, and one-half the cost of such work on non-Federal lands, the total estimated cost to the Federal Government to be approximately $796,844.

(2) The State of California, through its Department of Public Works, Division of Highways, will pay one-half the cost of the installation of road improvement work in aid of flood control on certain State roads, plus the cost of any necessary rights-of-way for such roads, the total estimated cost to the State to be approximately $147,300.

(3) The County of Los Angeles will pay one-half the cost of the installation of road improvement work in aid of flood control on certain county roads within the said county, plus the cost of necessary rights-of-way for such roads, the total estimated cost to the county to be approximately $97,455.

(4) The County of Ventura will pay one-half the cost of the installation of road improvement work in aid of flood control on certain county roads within the said county, plus the cost of necessary rights-of-way for such roads, the total estimated cost to the county to be approximately $1,000.

(5) The City of Glendale will pay one-half the cost of the installation of road improvement work in aid of flood control on certain city roads within the said city, plus the cost of necessary rights-of-way for such roads, the total estimated cost to the city to be approximately $2,000.

(6) The installation of necessary road-improvement work in aid of flood control on private roads, estimated to cost $63,402, will be performed pursuant to agreements between the County of Los Angeles and the private persons involved. As provided in item C, I, (1), above, the Secretary of Agriculture will provide one-half the cost of this work. Responsibility for the other half of the cost of this work on private roads will be provided for in the agreements between the county of Los Angeles and the private persons involved.

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II. Maintenance and replacement of measures.

(1) The Secretary of Agriculture, through the Forest Service, will be responsible for maintenance and replacement of road-improvement work in aid of flood control on Federal lands, the estimated average annual cost of which will be approximately $2,475.

(2) The State of California, through its Department of Public Works, Division of Highways, will be responsible for maintenance and replacement of road-improvement work in aid of flood control on certain State roads, the estimated average annual cost of which will be approximately $1,500.

(3) The County of Los Angeles will be responsible for maintenance and replacement of road-improvement work in aid of flood control on certain county roads within the said county, the estimated average annual cost of which will be approximately $1,300.

(4) The County of Ventura will be responsible for maintenance and replacement of road-improvement work in aid of flood control on certain county roads within the said county, the estimated average annual cost of which will be approximately $100.

(5) The City of Glendale will be responsible for maintenance and replacement of road-improvement work in aid of flood control on certain city roads within the said city, the estimated average annual cost of which will be approximately $100.

(6) Maintenance and replacement of road-improvement work in aid of flood control on private roads will be provided for in agreements to be entered into between the County of Los Angeles and the private persons involved. The estimated average annual cost of this maintenance work will be approximately $400.

D. MOUNTAIN CHANNEL IMPROVEMENT

I. Installation of measures.

(1) The Secretary of Agriculture, through the Forest Service, will pay the entire cost of the installation of mountain channel improvement work in aid of flood control on Federal lands, and one-half the installation cost of such work on non-Federal lands, the total estimated mountain channel improvement installation cost to the Secretary of Agriculture to be approximately $2,868,555.

(2) The Los Angeles County Flood Control District will pay one-half the cost of the installation of mountain channel improvement work in aid of flood control on non-Federal lands, plus the cost of rights-of-way for such work which it may become necessary to acquire from private or non-Federal public agencies, the total estimated cost to the district to be approximately $996,445.

II. Maintenance and replacement of measures.

(1) The Secretary of Agriculture, through the Forest Service, will be responsible for the maintenance and replacement of mountain channel improvement work in aid of flood control on Federal lands, the estimated average annual cost of which will be approximately $6,600.

(2) The Los Angeles County Flood Control district will be responsible for the maintenance and replacement of mountain channel improvement work in aid of flood control on non-Federal lands, the estimated average annual cost of which will be approximately $6,600.

E. FARM-LAND IMPROVEMENT AND TREATMENT

I. Installation of measures.

(1) The installation of measures of farm-land improvement and treatment in aid of flood control, including planning for individual farms and other units of land and application on measures, on non-Federal lands within the Los Angeles County flood-control district, will be provided for in cooperative agreements between the district and the owners and operators of the lands involved. These measures in aid of flood control may be installed in flood and silt source areas on non-Federal lands within the district, regardless of whether such lands are being used for agricultural purposes. The district may provide any funds, personal services, equipment, materials, or facilities that it desires to furnish and is able to obtain for carrying on this work. To assist the district in the prosecution of these measures of farm-land improvement and treatment, the Secretary of Agriculture, through the Soil Conservation Service, will make available to the district (*a*) machinery and equipment, (*b*) materials, (*c*) technical and other personnel, and (*d*) other facilitating services. The Secretary of Agriculture, through the Soil Conservation Service, may also furnish labor, such as that from Soil Conservation Service—C. C. C. camps, with facilitating C. C. C. equipment and C. C. C. materials. The total estimated value of the contribution by the Secretary of Agriculture for the installation of measures of farm-land improvement and treatment, including planning for individual farms and other units of land and application of measures, will be approximately $1,054,060.

(2) In carrying out the work provided for in the preceding paragraph, it is expected that the owners and operators of the lands involved will contribute approximately $1,120,058 in the form of labor, materials, and equipment.

II. Maintenance and replacement of measures.

(1) Adequate provisions governing maintenance and replacement of the above-mentioned measures of farm-land improvement and treatment in aid of flood control on non-Federal lands within the district will be included in the above-mentioned cooperative agreements between the district and the owners and operators of the lands involved. To assist the district in carrying out the maintenance and replacement provisions of these cooperative agreements, the Secretary of Agriculture, through the Soil Conservation Service, will furnish to the district such personnel and facilities as may be needed and available, provided that such assistance in maintenance work will be chargeable to Federal funds other than flood-control funds. Whenever any such cooperative agreement expires on account of change in ownership of the land involved, or on account of contingencies provided for in the cooperative agreement, the district, with the assistance of the Secretary of Agriculture, will attempt to secure a new cooperative agreement with the owner and operator of the land, providing for necessary maintenance and replacement of structures and measures in aid of flood control.

F. DEBRIS BASINS AND IMPROVEMENT OF MINOR CHANNELS

I. Installation of measures.

(1) The Secretary of Agriculture, through the Soil Conservation Service, will pay one-half the cost of the construction and installation of debris basins and minor channel improvements in aid of flood control on non-Federal lands within the Los Angeles County flood-control district, the total estimated cost to the Secretary of Agriculture for this purpose to be approximately $388,005.

(2) The Los Angeles County flood-control district will pay one-half the cost of the construction and installation of certain debris basins and minor channel improvements in aid of flood control on non-Federal lands within the district, the estimated cost to the district to be approximately $388,005, plus the cost of necessary rights-of-way.

II. Operation and maintenance.

(1) The Los Angeles County flood-control district will be responsible for operation and maintenance of debris basins and minor channel improvements in aid of flood control on non-Federal lands, the estimated average annual cost of which will be approximately $6,645.

Part 2

CONDITIONS AND LIMITATIONS

(1) As resources permit the carrying out of parts of the entire program described in the plan, the appropriate agency of the Department of Agriculture and the local agencies involved will enter into supplemental memoranda of understanding which will describe the work to be done, the procedures to be followed, the division of responsibility for the work, the estimated costs to each agency, and the fiscal and administrative arrangements to be followed in carrying out the plan.

(2) All measures carried out pursuant to this memorandum, which involve contributions by both the Department of Agriculture and a local agency, will be subject to inspection by duly authorized representatives of the Department and by duly authorized representatives of the local agency.

(3) No Federal money will be spent for work on non-Federal land until satisfactory supplemental memoranda of understanding between the Forest Service or the Soil Conservation Service, as the case may be, and the appropriate local agency or agencies above mentioned have been executed.

(4) No Federal money will be spent for application of measures of farm land improvement and treatment on non-Federal land, as provided in part 1, item E, until the owner thereof has entered into a cooperative agreement with the Los Angeles County flood-control district as provided in part 1, item E. Such cooperative agreements will be in a form satisfactory to the Soil Conservation Service.

(5) No Federal money will be spent for road-improvement work on a private road as provided in part 1, item C, until the owner thereof has entered into a cooperative agreement with the county of Los Angeles, as provided in items C, I, (6), and C, II, (6) of part 1. Such cooperative agreements will be in a form satisfactory to the Forest Service.

(6) The foregoing estimates of expenditures are given primarily for the purpose of indicating the proportionate expense of the program to the cooperating parties. The actual cost to each cooperating party for any single item or type of measure may vary from the estimates herein given: *Provided, however,* That the total of all expenditures for the construction and installation of measures by the Department of Agriculture will not exceed $8,379,635.

(7) None of the parties hereto will be expected to make any part of the expenditures herein provided for construction and installation of measures except pursuant to supplemental memoranda of understanding. No supplemental memorandum of understanding will be entered into until the parties to such supplemental memorandum are able to give reasonable assurance that they will have funds and facilities available to carry out the construction and installation of the measures to be undertaken pursuant to such supplemental memorandum: *Provided,* That any obligations of the Secretary of Agriculture for operation, maintenance, or replacement of measures will always be contingent upon the availability of funds for those purposes.

(8) Expenditures estimated herein will include only expenditures directly chargeable to work performed under the plan, and provided for in supplemental memoranda of understanding. Other expenditures which are necessary to finance activities of the parties, not provided for in supplemental memoranda of understanding, may not be counted as contributions to the work herein described.

(9) All rights-of-way across land not owned by the United States will be provided by the local agencies, as hereinabove provided, whether such rights-of-way are acquired in the name of the United States or in the name of a local agency; provided that rights-of-way to be used primarily for national forest purposes may be acquired by the Forest Service in the name of the United States.

(10) Each local agency which enters into a supplemental memorandum of understanding with the Forest Service or the Soil Conservation Service will hold and save the United States free from damages or claims due to the construction, installation, or operation of measures in aid of flood control pursuant to such supplemental memorandum. This provision will not be applicable to work prosecuted by the Secretary of Agriculture on Federal land.

(11) In case C. C. C. or W. P. A. or other similar federally financed public-works agencies are used to perform part of the work on non-Federal land, the services of such agencies will be considered part of the contribution of the Secretary of Agriculture, regardless of whether such services are sponsored by a local agency. However, where such services are sponsored by a local agency, the contribution supplied by the local sponsor will be regarded as part of the local agency's contribution in aid of flood control herein provided for. The value of the services of such federally financed public-works agencies which may be utilized on non-Federal lands will be determined in supplemental memoranda of understanding.

(12) Expenditures in aid of flood control which may be made by Federal agencies not herein mentioned will not be counted as part of the contribution of the Secretary of Agriculture.

(13) The contributions of the parties hereto may be in the form of money, labor, materials, machinery, equipment, personal services, or other necessary facilities. The form of the contribution and the value

thereof may be determined in supplemental memoranda of understanding.

(14) Definitions:

(*a*) "Federal land," as used in this memorandum, shall include (1) all land owned by the United States, except areas within rights-of-way for roads across federally owned land which have been or hereafter may be granted or reserved to private persons or private or non-Federal public agencies; and (2) areas within rights-of-way for roads or other improvements which have been or hereafter may be acquired by the United States within or adjacent to the exterior boundaries of the Angeles National Forest.

(*b*) "Local agency," as used in this memorandum, includes any of the parties hereto except the Secretary of Agriculture.

Part 3

THE IMMEDIATE PROJECTS

In view of the fact that the Secretary of Agriculture now has available the sum of $1,410,000 for watershed work in aid of flood control in the Arroyo Seco and San Fernando Valley, the parties hereto will initiate the program by installing the measures in aid of flood control which are included in the plan for the Arroyo Seco and San Fernando Valley as follows:

1. *In the Arroyo Seco.*—(*a*) The Secretary of Agriculture will spend approximately $1,180,000 as follows: $250,000 for fire control; $60,000 for forest cover improvement; $169,800 for road improvement; $690,700 for mountain channel improvement; and $9,500 for farm-land improvement and treatment on non-Federal lands.

(*b*) The State of California, Department of Public Works, Division of Highways, will spend approximately $53,300 for road improvement.

(*c*) The County of Los Angeles will spend approximately $11,500 for fire control.

(*d*) The County of Los Angeles will spend approximately $25,500 for road improvement.

(*e*) The Los Angeles County Flood Control District will spend approximately $2,600 for minor channel improvement.

2. *In the San Fernando Valley.*—(*a*) The Secretary of Agriculture will spend approximately $230,000 on measures of farm-land improvement and treatment on non-Federal land.

This memorandum of understanding shall be effective when signed by the parties agreeing hereto and shall remain effective for a period of 10 years. It shall be automatically renewed for a 10-year period at the end of the first and each succeeding period; provided that, as between the Secretary of Agriculture and any local agency, it may be terminated at any time by mutual consent of the Secretary of Agriculture and such local agency.

THE COUNTY OF LOS ANGELES,
By ROGER W. JESSUP.

The signing of this memorandum of understanding by Roger W. Jessup, on behalf of the County of Los Angeles was authorized by a resolution of its board of supervisors, adopted at a meeting held on the 17th of December 1940.

L. E. LAMPTON,
Clerk, Board of Supervisors of the County of Los Angeles, Calif.,
By ALICE BURKS, *Deputy*,
THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT,
By ROGER W. JESSUP.

The signing of this memorandum of understanding by Roger W. Jessup on behalf of the Los Angeles County Flood Control District was authorized by a resolution of its board of supervisors, adopted at a meeting held on the 17th of December 1940.

L. E. LAMPTON,
Clerk, Board of Supervisors of Los Angeles County, Flood Control District, California.
By ALICE BURKS, *Deputy*,
THE CITY OF LOS ANGELES,
By R. L. BURNS.

The signing of this memorandum of understanding by R. L. Burns on behalf of the City of Los Angeles was authorized by a resolution of its city council, adopted at a meeting held on the 2d of January 1940.

WALTER C. PETERSON,
Clerk, City Council of Los Angeles, Calif.

THE CITY OF GLENDALE,
By EDWIN A. INGHAM.

The signing of this memorandum of understanding by ——— ——— on behalf of the City of Glendale was authorized by a resolution of its city council, adopted at a meeting held on the 3d of December 1940.

C. E. CHAPMAN,
Clerk, City Council of Glendale, Calif.

THE COUNTY OF VENTURA,
By P. W. DENNIS.

The signing of this memorandum of understanding by P. W. Dennis on behalf of the County of Ventura was authorized by a resolution of its board of supervisors, adopted at a meeting held on the 3d of December 1940.

L. E. HALLOWELL,
Clerk, Board of Supervisors of the County of Ventura, Calif.,

THE STATE OF CALIFORNIA, DEPARTMENT OF PUBLIC WORKS, DIVISION OF HIGHWAYS,

By C. H. PURCELL, *State Highway Engineer*,

GROVER B. HILL,
Acting Secretary of Agriculture of the United States.

Date: January 22, 1941.

EXHIBIT B.—*Improvement program for the Los Angeles River watershed*

ESTIMATED INSTALLATION COSTS OF MEASURES IN AID OF FLOOD CONTROL

	Secretary of Agriculture	State of California	Los Angeles County	Los Angeles city	Glendale city	Ventura County	Farmers and other individuals
Fire control	[1] $3,197,751		$112,233	$140,337			
Cover improvement	74,420						
Mountain-road improvement	[1] 796,844	$147,300	97,455		$2,000	$1,000	$31,701
Mountain-channel improvement	[1] 2,868,555		996,445				
Farm-land improvement	1,054,060						1,120,058
Debris basins and channels	[1] 388,005		388,005				
Total	8,379,635	147,300	1,594,138	140,337	2,000	1,000	1,151,759

[1] Includes 50 percent of the total estimated installation costs of measures on non-Federal lands exclusive of right-of-way costs.

EXHIBIT C.—*Improvement program for the Los Angeles River watershed*

AVERAGE ANNUAL COSTS OF OPERATION, MAINTENANCE, AND REPLACEMENT OF MEASURES IN AID OF FLOOD CONTROL

	Secretary of Agriculture	State of California	Los Angeles County	Los Angeles city	Glendale city	Ventura County	Farmers and other individuals
Fire control	$298,438		$30,000	$6,000			
Cover replacement	450						
Mountain-road improvement	2,475	$1,500	1,300		$100	$100	$400
Mountain-channel improvement	6,600		5,000				
Farm-land improvement	[1]						177,963
Debris basins and channels			6,645				
Total	307,963	1,500	42,945	6,000	100	100	178,363

[1] Amount not estimated and not chargeable to flood-control funds.

EXECUTIVE OFFICE OF THE PRESIDENT,
BUREAU OF THE BUDGET,
Washington, D. C., September 28, 1940.

The honorable the SECRETARY OF AGRICULTURE.

MY DEAR MR. SECRETARY: Presidential approval has been obtained for the release of $1,410,000 from the existing Budget reserve under that portion of the appropriation "Flood control, general," transferred from the War Department to the Department of Agriculture, for the initiation of erosion prevention and waterflow retardation work on a demonstration basis in the Arroyo Seco and San Fernando units of the Los Angeles River Basin, in accordance with the Department's plan submitted June 14, 1940.

The use of these funds shall be subject to the following limitations:

1. No part of this allocation shall be used in the District of Columbia.

2. Any savings in this allocation resulting from the use of Work Projects Administration and Civilian Conservation Corps funds shall be returned to the Budget reserve.

The General Counsel of the Bureau of the Budget in his opinion of September 21, a copy of which is attached, concurs with the opinion

of the Acting Solicitor of the Department of Agriculture that flood-control funds are available for repair and maintenance, as well as construction. In view of these decisions, it is suggested that your records be maintained in such manner that works constructed under this fund which will require subsequent maintenance financing, can be readily segregated from similar works constructed through the use of funds regularly available to the Department for similar purposes.

Please forward the necessary Form C, Modification of Apportionments, covering this allocation as early as possible.

Very truly yours,

JOHN B. BLANDFORD, JR.,
Assistant Director.

BUREAU OF THE BUDGET

INTRAOFFICE MEMORANDUM

SEPTEMBER 21, 1940.

To: Mr. Broadbent.
From: E. G. Kamp.
Subject: Los Angeles River flood-control project.

On a strict construction of the language of Public, No. 761 of June 28, 1938, and the Appropriation Act of June 11, 1938 (52 Stat. L. 671) it is quite doubtful that the use for repairs and maintenance of the funds made available therein to the Secretary of Agriculture for prosecution of works of improvement (for measures of waterflow retardation and soil-erosion prevention on watersheds, etc.) would be authorized.

An improvement is defined in Webster's new international dictionary as "a valuable addition or betterment, as a building, clearing, drain, fence, etc., on land."

This view appears to be further supported by the circumstance that later appropriation acts use the language "for construction and maintenance" whereas the act of June 11, 1938, omits maintenance. In earlier appropriation acts also, provision is specifically made for maintenance on certain projects.

In the basic Flood Control Acts of 1936 and 1938, the several projects therein authorized, including the Los Angeles River project, are described as "the following works of improvement." The scope of the work on each project is defined in an official report or other document to which reference is made in the statute. An examination of the plan for the Los Angeles River project would disclose whether maintenance was included. It probably was not.

On the other hand, according to section 7 of the 1938 act, Public, No. 761, these works of improvement on watersheds which the Secretary of Agriculture is authorized to prosecute are expressly designed "to correlate the program for the improvement of rivers and other waterways by the Department of War with the program for improvement of watersheds by the Department of Agriculture" and otherwise to effectuate the policy of the 1936 act. Later appropriations for 1940 and 1941 for flood-control projects expressly include mainte-

nance.[1] Effective correlation between waterway and watershed improvements therefore seems to require maintenance of watershed improvements. The addition of maintenance in the 1940 and 1941 Appropriation Acts discloses an intention to provide for current maintenance of these correlated projects. The use of the funds for current maintenance, so far as that is necessary to correlate the program of watershed improvement with the program of waterway improvement, would seem to be in accordance with the intention of the Congress as expressed in the 1938 enactment.

In a broad sense too it is possible to regard repairs and current maintenance as "Works of improvement." The narrower construction, as pointed out by the Acting Solicitor for Agriculture, might lead to absurd results, especially if no other appropriation were available for maintenance.

It is to be noted that the improvements are to be prosecuted "under plans to be approved by the Secretary of Agriculture". It is assumed that maintenance and repairs will be made in accordance with such plans.

One other point merits attention. "Except as otherwise specifically provided by law" the provisions of section 3 of the 1936 act are made applicable to all flood-control projects by section 2 of the 1938 act, but only "as heretofore amended and as herein further modified." The provisions of section 3 require assurance by local governments to the Secretary of War that they will provide lands or rights-of-way and will maintain and operate all works after completion. This requirement was modified, however, in the 1938 act so as to exclude "any dam and reservoir project, or channel improvement or channel rectification project for flood control." This exception appears to be applicable to the Los Angeles River project, which is described in the 1936 act as amended on May 15, 1937, as "construction of reservoirs and principal flood channels" in the Los Angeles River and tributaries thereof.

It might be argued that the requirement of local maintenance, etc. is applicable only to projects that are under the jurisdiction of the Secretary of War but the 1938 act makes them applicable to all flood-control projects with the exception above stated. Congress evidently intended as a general thing to shift the burden of maintaining flood-control works onto the local governments, thereby strengthening the view that when it passed the 1938 act it did not intend to provide for maintenance except insofar as a project would come within the above exception.

Whether the requirement of local maintenance is applicable to the watershed improvements connected with the Los Angeles River improvement is a question, however, that would properly arise before any expenditures were undertaken with respect to such an improvement. Apparently, it was heretofore decided or assumed, when the work was first undertaken, that the requirement of local maintenance was not applicable to this project.

[1] It is not intended to imply that the maintenance provided for in the 1940 and 1941 flood-control appropriations of the War Department is applicable to watershed improvements prosecuted by the Department of Agriculture. So far as watershed improvements are concerned, they are expressly made available in these two enactments only for preliminary examinations and surveys by the Department of Agriculture, and this very circumstance might be cited further to support the view that Congress did not intend to provide for maintenance of watershed improvements previously authorized, else it would have done so. On the other hand, as pointed out above, provision being thus made for maintenance of waterway projects under the control of the War Department, a broader construction of the 1939 appropriation for Agriculture seems appropriate, since effective correlation of the programs requires maintenance also of watershed improvements.

It would seem reasonable moreover to view the watershed improvement as a part of the main improvement, and view it all as one project. Accordingly, if the Los Angeles project is within the exception, as it appears to be, the watershed improvement might well be regarded as within the exception also, even if it were otherwise subject to the requirements of section 3 of the 1936 act with respect to local maintenance. This is a practical question that must be decided in the light of the physical facts and one which has apparently already been determined by administrative action.

It seems proper to conclude, therefore, that moneys made available to the Secretary of Agriculture by the act of June 11, 1938, for the prosecution of works of improvement for measures of water-flow retardation, etc., on watersheds, may be used for repairs and maintenance thereon, especially in those cases that come within the exception stated in section 2 of Public, No. 761.

War Department,
Office of the Chief of Engineers,
Washington, June 19, 1940.

Mr. M. S. Eisenhower,
Land Use Coordinator, Department of Agriculture,
Washington, D. C.

Dear Mr. Eisenhower: Reference is made to your letter dated June 7, 1940, and to the conference held in this office concerning the Department of Agriculture's report on the Los Angeles River watershed, recommending a program of soil-erosion prevention and water-flow retardation in aid of flood control.

The report has been reviewed by members of this Department and several items of relatively minor importance have been adjusted at a second conference with your representatives.

Your report presents a well-considered plan for the control of areas lying above the limits of the flood channels, debris basins, and reservoirs proposed by this Department in its plan for flood control of the Los Angeles River. The program recommended in your report is in harmony with and a desirable complement to the work proposed by this Department.

Very truly yours,

Thomas M. Robins,
Brigadier General,
Assistant to the Chief of Engineers.

June 14, 1940.

Memorandum for the Secretary

Dear Mr. Secretary: We are submitting to you for your approval the attached report which recommends for the Los Angeles River watershed a program of run-off and water-flow retardation and erosion prevention in aid of flood control. The recommended program is complementary to, and in harmony with, the downstream structural program of the War Department and local flood-control agencies.

The Department of Agriculture's survey of the watershed has been a cooperative undertaking of the Bureau of Agricultural Economics, the Forest Service, the Soil Conservation Service, and the Office of Land Use Coordination. Other interested agencies, notably the Los Angeles County flood-control district and the Corps of Engineers, have been consulted during the progress of the survey and informally have expressed approval of the proposed program.

We feel that, owing to the nature and magnitude of the flood problem in the watershed, and the benefits that will accrue from the land-treatment program, the Los Angeles River Watershed should be the first on which operations should proceed under the Flood Control Act of June 22, 1936. We therefore earnestly recommend your approval of the attached report and its transmittal to the President.

The Forest Service and the Soil Conservation Service, the two agencies of the Department which will carry on the operations, are ready to begin work as soon as authorization is granted. We therefore recommend that from the $4,000,000 appropriated by the Congress the sum of $1,410,000 be allotted to begin work in the Arroyo Seco and San Fernando portions of the watershed.

Respectfully submitted.

H. R. Tolley,
Chief, Bureau of Agricultural Economics.
H. H. Bennett,
Chief, Soil Conservation Service.
Earl H. Clapp,
Acting Chief, Forest Service.
M. S. Eisenhower,
Land Use Coordinator.

Approved, June 14, 1940.

H. A. Wallace, *Secretary.*

CONTENTS

SUMMARY OF RECOMMENDATIONS

A program of waterflow retardation and soil-erosion prevention in aid of flood control is recommended for the Los Angeles River watershed under the Flood Control Act of June 22, 1936, Public, No. 738, Seventy-fourth Congress, and under Public, No. 761, Seventy-fifth Congress, and Public, No. 591, Seventy-fifth Congress.

It is recommended—

1. That the sum of $8,379,635 be expended by the Department of Agriculture for the above-mentioned program.

2. That of this sum, $1,884,775 be expended only on condition that State or local agencies cooperate by (1) expending an approximately equal sum to pay for half the cost of installing certain measures on non-Federal lands and on roads maintained by non-Federal agencies, (2) acquiring whatever rights-of-way are necessary, and (3) assuming responsibility for the operation, maintenance, and replacement of measures and structures. That portions of this sum be expended as soon as State or local agencies agree to cooperate in installing particular units of work.

3. That the sum of $1,410,000 be allocated immediately, out of the $4,000,000 now available to the Department of Agriculture for flood-control purposes, to begin work on the Los Angeles River watershed, and that this sum be spent in such ways as to complete in the shortest possible time installation of all measures on the watershed of Arroyo Seco and farm-land measures on about 33 square miles in San Fernando Valley.

4. That the Department of Agriculture undertake immediately the work to be done on Federally owned land; that it arrange, through the Los Angeles County flood-control district, to cooperate with farmers in getting the measures for farm-land improvement and treatment under way; and that it negotiate immediately with the Los Angeles County flood-control district to seek a cooperative agreement to provide for sharing the cost of structures recommended on non-Federal land and non-Federally maintained roads.

For the Los Angeles River watershed, as a whole, the measures recommended for installation, and the amount of Federal flood-control funds required for each, are as follows:

1. Fire control, including fire-truck roads, tank trucks, crew stations, firebreaks, and communications	$2, 888, 751
2. Cover improvement, including direct seeding in bare areas, areas of depleted cover, and recently burned areas	64, 420
3. Road improvement, including improved drainage and slope stabilization by engineering works and planting	673, 844
4. Mountain-channel improvement, including the construction of barriers, revetments and deflectors, channel clearing, and occasional channel changes	2, 425, 555
5. Farm-land improvement and treatment	991, 820
6. Debris basins and improvement of minor channels	355, 245
7. Contingent fund	980, 000
Total	[1] 8, 379, 635

[1] The distribution of the "contingent fund" makes the above totals: Fire control, $3,197,751; cover improvement, $74,420; mountain-road improvement $796,844; mountain-channel improvement, $2,868,555; farm-land improvement $1,054,060; debris basins, $388,005.

In addition to the above expenditures from Federal flood-control funds, State and local governments must contribute $1,884,775 and farmers and other individuals must expend $1,151,759 in the form of labor and materials to effectuate the program. The estimated total installation cost is $11,416,169, or approximately $11,500,000.

It is estimated that for operations, maintenance, and replacement an average annual sum of $495,914 will be required. Of this total there will be expended from flood-control funds, by the Federal Government, approximately $308,000 annually; from State and local governments, approximately $51,000; and farmers, in cooperation with the Los Angeles flood-control district, will contribute approximately $178,000 to maintain and continue the farm-land measures and practices.

It is estimated that the installation of the program will yield the following benefits:

Type of benefit and value during period of 50 years [1]	
1. Reduction in flood damage from impact of water and debris and from inundation	$15, 671, 782
2. Reduction of silt and debris deposition	6, 216, 797
Total benefits from reducing flood damage	21, 888, 669
3. Water conservation	1, 207, 409
4. Reduction in property loss by fire	1, 349, 450
5. Reduction in fire-suppression costs	228, 300
6. Reduction in road-maintenance costs	711, 764
7. Protection and extension of mountain recreational areas	735, 994
8. Soil-conservation benefits	15, 911, 276
Total benefits	42, 032, 862

[1] Value of future benefits discounted to the present time at 3-percent interest.

The total cost of the program for 50 years, including the cost for operation, maintenance, and replacement discounted to its present value on the same basis as the above value of benefits, is $22,781,207, giving a ratio of $1.85 in benefits to each dollar of cost.

INTRODUCTION

Southern California presents a flood-control problem as critical as any in the United States, owing to the proximity of highly developed and densely settled urban areas to rugged mountain ranges which periodically project violent flood flows upon the settled plains.

This report deals with the Los Angeles River drainage area, one of three contiguous watersheds lying in the South Pacific Basin in California.[1] The combined area in these 3 watersheds is 4,000 square miles, of which 839 square miles are in the Los Angeles watershed.

Los Angeles and nearby cities are located on an alluvial plain, about 30 miles wide, lying between the Pacific Ocean and the San Gabriel Mountain Range. From the outwash fans at the northern edge of this alluvial plain to the tops of the higher peaks there is a difference in elevation of as much as 4,500 feet. In the mountainous area the steep-sided canyons have channel gradients ranging up to 3,000 feet per mile. The mountains themselves are formed largely of granitic rock, heavily faulted and deeply weathered, yielding large quantities of rock debris by normal erosional processes.

[1] The 3 watersheds mentioned include those of the Los Angeles, San Gabriel, and Santa Ana Rivers.

When the characteristic local storms of high intensity occur, the steep canyons of these mountains discharge torrential flows upon the agricultural, suburban, and urban areas lying along the mountain front at the edge of the valley floor. Storms of that type, and even storms of less intensity, cause considerable movement of silt, sand, and fine gravel from agricultural lands in the valley onto streets, roads, agricultural and urban land, and into the drainage systems.

The intensity of the torrential flows from the mountains, and the damages caused by the debris and boulders which they transport, increase to an astonishing degree whenever the mountain watershed is denuded by forest fire. Damages resulting from these local torrential floods are out of all proportion to the size of the area from which the floods originate. They are greatest where communities or intensively cultivated agricultural lands lie on the alluvial fans immediately below the canyon mouths, or where they extend into the canyons themselves.

Population and wealth in the metropolitan area of Los Angeles have more than quadrupled since 1900. In that part of the metropolitan area lying within the Los Angeles watershed the increase has been sixfold to eightfold.

The agricultural land on the slopes between the south front of the San Gabriel Mountains and the ocean, and in the San Fernando Valley, is interspersed between urban and suburban centers. The agriculture is of the most intensive type, and the agricultural value of the land is very high. Great areas are devoted to producing citrus fruit, deciduous fruit, nuts, truck crops, and to other special uses. Agriculture in the valley area depends almost completely on irrigation.

Local water supplies for both urban and agricultural uses have been overdrawn for many years and are supplemented by importations from the east slope of the Sierra Nevada and the Colorado River. The two aqueducts carrying these imported waters, each nearly 300 miles long, represent an investment of approximately $225,000,000.[2] In view of this situation any program in aid of flood control in the Los Angeles Basin must take into account the effect of the proposed work upon conservation of the local water supplies.

Practically the entire area covered by this report lies within Los Angeles County. A considerable portion of the agricultural land lies within the city limits of Los Angeles.

The county and the several cities in the danger zones are keenly aware of the risks involved and have spent large sums of money on corrective and preventive measures. The principal agencies doing such work are the Los Angeles County flood-control district, the Los Angeles County division of forestry, and the public-works departments of the county and of the cities. The Federal Government also has made large expenditures for construction of flood-control reservoirs and channel improvements in the valley and for the protection of the forest cover in the mountainous portion of the watershed.

Table 1 presents a simplified summary of the use of land within the Los Angeles watershed.

[2] Engineering News, July 3, 1913, and Engineering News-Record, November 24, 1938.

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TABLE 1.—*Dominant land uses in the Los Angeles watershed*

Type of land and use	Total acres	Percent	Type of land and use	Total acres	Percent
Rough and broken (brush and woodland)	232, 695	43. 4	Recreational uses	13, 191	4. 3
Agriculture and grazing	116, 065	21. 6	Public utilities	5, 849	1. 1
Intensive residential	123, 657	23. 0	Institutions	1, 761	. 4
Extensive residential	15, 473	2. 9	Vacant	9, 902	1. 8
Industry, gas and oil	12, 105	2. 2	Grand total	536, 909	100. 0
Commercial uses	6, 211	1. 1			

Forty-three percent of the area is of the foothill and mountain type of land; and 57 percent is of the benchland and valley type, of which 22 percent is devoted to agriculture, 26 percent to residential use, and 9 percent to miscellaneous uses. A large part (145,000 acres) of the mountain area is in the Angeles National Forest, established in 1892 and dedicated to watershed protection. Work done in parts of the Angeles Forest represents practically the only organized effort to deal with the flood problem in the mountain area, but funds have been insufficient to deal with it adequately.

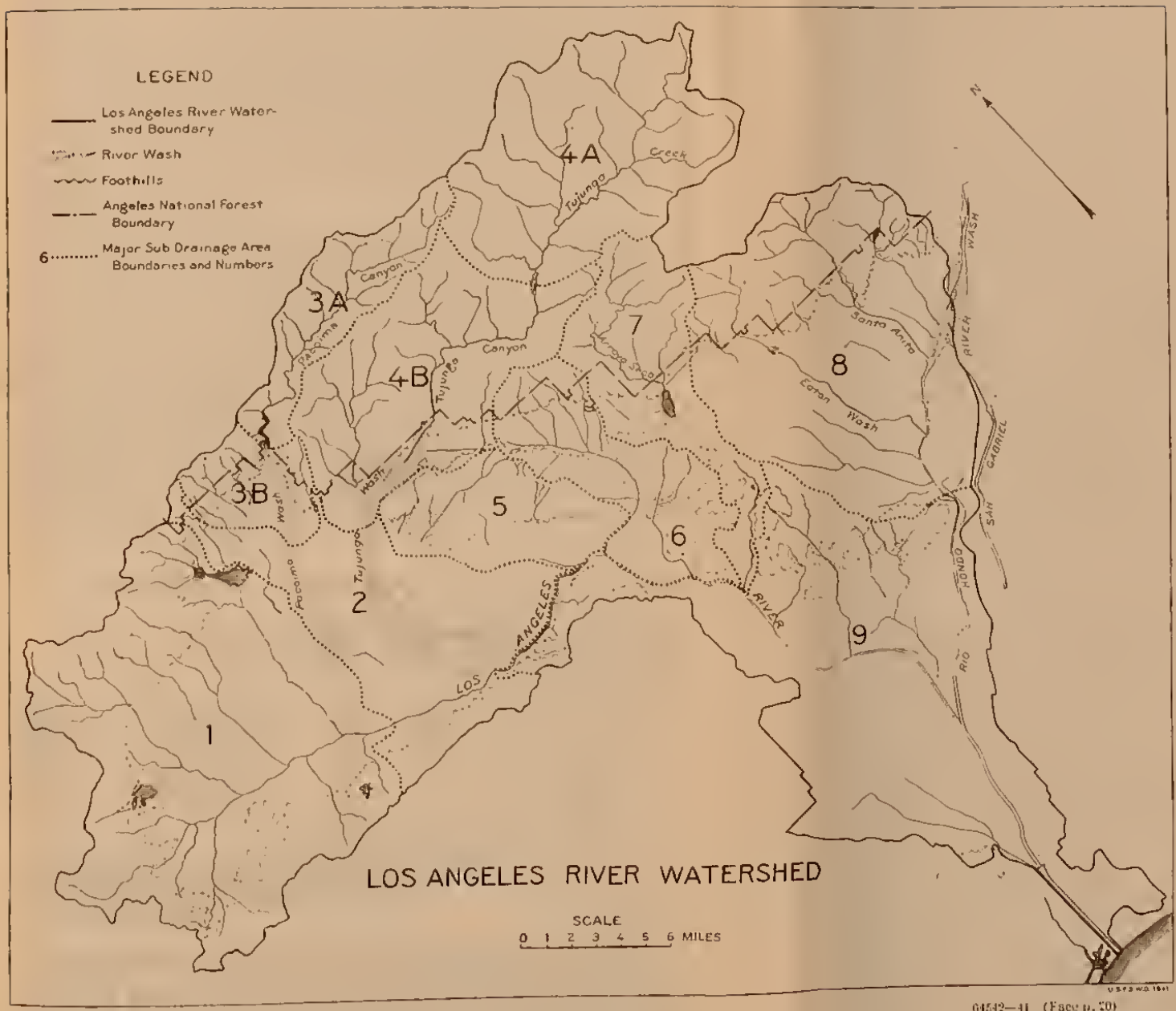
The program presented in this report for the improvement of the watershed in aid of flood control does not duplicate any work now sponsored or proposed by local agencies, nor work proposed or under way by other Federal agencies. It represents a plan of attack on the flood problem by treating the mountain portions of the watersheds to prevent excessive debris movement, and by introducing land-use measures in the valley areas to reduce damages originating on agricultural lands. In both areas the remedial measures will also conserve local water supplies by increasing infiltration and keeping run-off waters clear and usable.

Local interests and the population generally are aware of the need for such measures in aid of flood control, and are looking to the Federal Government to develop a remedial program.

FLOOD AND EROSION DAMAGES

Flood damage in the Los Angeles watershed occurs in many forms, beginning with the erosion of denuded or poorly protected mountain slopes by overland flow, and ending with the clogging of the Los Angeles Harbor by the flood-borne sediments. Damages which the program of the Department of Agriculture is designed to forestall are those resulting from the violence of rushing waters, from soil erosion, from the deposition of flood debris in places where it is not wanted, and from the destructive impact of mud-rock flows upon properties. In both mountain and agricultural areas these damages are greatest when extensive areas of bare soil are exposed to severe storms characterized by prolonged rains and high intensities.

Where forest cover on mountain slopes has been recently burned, sheet and gully erosion carry away not only soil and seed essential to future growth but the remnants of surface litter and organic matter in the topsoil which are essential to maintaining normal infiltration capacities. Mountain roads and trails are blocked by slides, culverts are plugged by flood debris, and stretches of road are washed out by the overflow. In the canyon bottoms, roads, camp grounds, and picnic



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sites are buried by slides from the slopes or by flood deposits of mud and boulders, or they are cut away by waters suddenly diverted from their normal course by flood debris. Bridges, cabins, resorts, and administrative buildings are damaged or destroyed by the impact of boulder-laden flows. Groves of trees, essential assets for the recreational use of the canyons, are undercut, broken or destroyed.

Water diversion and intake structures, pipe lines and transmission lines belonging to water and power companies and municipalities, are broken by impact, buried under tons of debris or sometimes destroyed altogether. In addition, direct losses of water are sustained during and after floods because the muddy water often cannot be used for days or weeks at a time.

Somewhat similar losses in water conservation are suffered in the water spreading systems at the canyon mouths and on adjacent slopes of the alluvial cones. Diversion works for spreading grounds are broken or filled with boulder debris, the spreading grounds themselves, if used, are silted up or much water is lost because it is too muddy for spreading and must be permitted to run to the ocean. If silt-laden floodwaters are spread the grounds are soon sealed, infiltration becomes negligible, and the grounds must be reconditioned either by removal of the silt or by cultivation.

The deposition of flood debris in reservoirs and basins at the canyon mouths along the mountain front is a form of damage that may be expressed either in terms of lost storage capacity or in cost of removal of the debris. The magnitude of these losses is indicated in table 2 which gives data on eight such structures in the Los Angeles watershed Several of these reservoirs are dual-purpose flood-control and water-conservation structures.

TABLE 2. *Siltation of reservoirs in the Los Angeles River Watershed* [1]

Reservoir	Date of completion of dam	Drainage area in square miles	Original capacity acre-feet	Loss in capacity to April 1938 acre-feet	Loss in cubic yards per square mile per year	Percent of original capacity lost to April 1938
Pacoima	February 1929	27.77	6,060	968	6,250	16.0
Devils Gate	June 1920	30.62	4,608	[2] 1,643	4,810	35.6
Sierra Madre	February 1928	2.39	49	41	2,770	83.7
Santa Anita	March 1928	10.82	1,068	385	5,750	27.7
Sawpit	June 1927	3.27	476	156	6,820	32.8
Tujunga No. 1	July 1931	81.35	6,240	1,520	4,320	24.4
Eaton	February 1937	9.48	940	245	41,700	26.1
Sunset Canyon	November 1929	.44	6	[3] 6.6	2,421	110.0
Total		166.14	19,447	4,964.6	[4] 5,250	25.5

[1] Data from Los Angeles County flood-control district report by M. F. Burk, Flood of Mar. 2, 1938, except for the Big Santa Anita, which are from Soil Conservation Service sedimentation studies.
[2] Includes gravel sales by city of Pasadena, 47 acre-feet removed.
[3] Includes 2.6 acre-feet removed in desilting reservoir since 1929.
[4] This is a weighted average.

Damages beyond the canyon mouths affect both agricultural and urban areas. The alluvial fans along the edges of the valley floor are extensively cultivated or developed as urban or suburban residential communities. Consequently, the damage from violent and erratic flood flows through these areas reaches large proportions. New channels are cut through fields, vineyards, orchards, and even through the lawns and gardens of the residences. Trees in orchards and wind-

breaks are uprooted or sometimes buried several feet under sand and boulders.

Due to the flattening of channel gradients or the clogging of culverts and bridges, deposition of transported material occurs at many points in the channels and subsequent flows leave old channels to cut new ones through developed lands. Debris is deposited on highways, roads and railroads, disrupting traffic and incurring great expense for removal. Deposition in city streets, lawns, and gardens entails similar damages. Residences and other buildings, bridges, and power lines are damaged or sometimes completely wrecked by the impact of huge boulders transported by a flood.

A recent example of a flood with these characteristics occurred in the La Crescenta-Canada Valley on New Year's Eve 1934. In this instance the debris flows issued from a fire-denuded mountain area of 7.5 square miles which had been burned the previous November.

In describing this flood, Eaton states: [3]

> Beginning almost exactly at midnight on December 31, 1933, and lasting for an hour, the resulting succession of debris flows caused 30 deaths; 483 homes were either completely swept away or rendered uninhabitable; and the total property damage aggregated $5,000,000.
>
> Practically all of the debris was deposited within the 1-hour period after midnight, occurring in a succession of about 15 sharp debris flows, moving at velocities estimated at from 5 to 10 feet per second. Canyon velocities were considerably greater. Each sharp peak of major debris flow would be succeeded by a rapidly moving stream which contained less debris cutting the channel to one side or through the deposited debris masses. It is estimated that the flows containing maximum percentages of debris occupied about 30 minutes.

The destructive force of such flows is illustrated by the manner in which the American Legion hall in Montrose was wrecked during the night. A boulder-laden stream, moving overland, crashed through the middle of the building leaving great holes in the uphill and downhill walls. Of the many persons who had gathered in the building, believing themselves safer than in their own homes, 12 were carried to their deaths in the disaster. During the flood upwards of 600,000 cubic yards of mud-and-boulder debris were deposited on the valley floor—on fields, highways, village streets, home grounds, and gardens.

Estimates, based on the measurement of deposition during the past 20 years in reservoirs and basins along the San Grabriel Mountain front, indicate an average debris movement rate from the mountain area of 3,500 cubic yards per square mile per year.

On the agricultural lands of the valley floor and the alluvial cones, flood damages of a less spectacular nature occur wherever such lands are not adequately protected by cover crops or by proper land-use practices. These damages are in the form of direct loss of topsoil by sheet erosion and rill erosion, the silting up of storm drains and channels, the deposition of unwanted soil on lower lying lands, and the development of deep, vertical-sided arroyos through fields and orchards.

These obvious physical damages entail other damages which are less apparent but nonetheless real, as follows: lowered productivity through loss of fertile topsoil, and through actual loss of productive surface area as gullies and arroyos grow larger; increased operating costs from the necessity of bridging or detouring around the growing gullies and arroyos; lessened infiltration of rainfall on the bare soil

[3] Eaton, E. Courtlandt, Flood and Erosion Control Problems and their solution, Paper No. 1950, Transactions, American Society of Civil Engineers 1934, pp. 1319–1322.

surfaces and hence a lessened local contribution to underground supplies. The eroded soil from these lands is deposited not only on other agricultural lands, where it is more often detrimental than beneficial, but also on roads, and streets and on residential property in the towns, in storm drains and stream channels, in the Los Angeles River, or in Long Beach harbor. The rates of such detrimental soil movement from the agricultural lands in the Los Angeles watershed vary within wide extremes, but the average over the whole valley is conservatively estimated at 1,000 cubic yards per square mile per year.

It will be noted that the damages listed may nearly all be attributed directly or indirectly to soil erosion, to the movement of erosion debris, its deposition, or the force of its impact on property. Naturally the debris is moved by water, but the damages are done by the solid rather than the liquid portions of the debris-laden floods. The remedial measures to be applied by the Department of Agriculture, both in the mountains and in the valley of the Los Angeles watershed, are aimed primarily at reducing this soil and debris movement. The main objective is stated in this manner in order to emphasize the significance of debris movement rather than to minimize the importance of water flow retardation in the upstream flood-control plan.

In this place in the report no attempt has been made to assign values to past damages of the types described. Careful estimates of the damages which will be prevented or reduced by the program of the Department of Agriculture are presented in terms of cash value in the section headed "Analysis of Costs and Benefits."

1938 Flood Damages

The storm of March 1938 was general over southern California; it was a storm of large magnitude and the damages were severe. A more accurate tabulation of damages is available for this storm than for any previous major storm. Damage done in the Los Angeles River watershed was estimated to be $37,693,000. This figure does not include damage due to deposition in reservoirs and debris basins or loss of topsoil. It probably does not include a considerable amount of scattered local damage to suburban and agricultural property which owners absorbed without report.

Probable Damage From Future Floods

Estimates of probable future flood damages over a 50-year period, based on watershed conditions and improvements as they existed in 1938, were calculated to be $256,000,000 for the Los Angeles watershed. Additional future damages as a result of increased values on the watershed, which may be expected to accompany an estimated 53 percent increase in population, are estimated at $61,000,000. An additional $12,000,000 may be added for probable flood damages resulting from storms following large brush fires in the mountain areas.

The damages thus theoretically developed are from expected storms of sufficient magnitude to produce flood stage run-off down the main channels. When the downstream program is completed a very large part of the damages covered by the estimate above will be prevented. However, some damages included in the total will still occur because

they take place on the watershed area rather than along the waterways.

The damage estimate is based on a survey by the United States Engineer Corps following the 1938 flood, supplemented by a later survey made by the Department of Agriculture to include local damages to agricultural lands and to foothill and mountain areas above the main channels.

The damages resulting from the improper use of agricultural lands are naturally greatest during floods, yet it is the accumulation of damage caused by lesser storms occurring annually that lifts high the total. Such storms are not of sufficient magnitude to be of concern in connection with downstream works such as those proposed by the United States Corps of Engineers. Therefore, benefits from the agricultural program must be determined largely by independent analysis of the source, quantity, and deposition of debris and silt from agricultural lands rather than by direct and exclusive use of the damage estimates developed from the survey of the 1938 flood.

Even if flood-stage records and damage records were available, their usefulness would be limited in forecasting probable future damages for the Department of Agriculture program and in designing many types of remedial measures. In general, local flood damages are caused by, and generally are proportional to, the amount, movement, and deposition of silt, sand, and debris. The movement and quantity of debris depend on many conditions other than the flood stage. Furthermore, the distribution of silt, sand, and debris onto streets, roads, and lands, and into reservoirs depends more on the combined effect of many storms of less than flood magnitude than on occurrence of a few major flood-producing storms.

The lands most subject to the types of damages which can be averted by the Department of Agriculture program—damages which are caused by floods originating in the mountains—are those adjoining the washes across the alluvial fans. These lands are threatened when a stream changes its channel. This occurrence is unpredictable and may occur at less than high flood stage. Consequently, the amount and location of damages from mountain streams are difficult to predict in relation to flood stages. The situation is further complicated when the mountain cover is destroyed by fire—a possibility unrelated to storm pattern but of controlling influence on soil movement. Accordingly, benefits from the mountain program have been estimated independently of the probable 50-year storm damages.

EXISTING AND PROPOSED FLOOD-CONTROL WORK OF ALL AGENCIES

A program for watershed improvement in aid of flood control must necessarily be in harmony with programs proposed, under way, or completed by other agencies. In the case of the Los Angeles watershed several agencies have done flood-control work. The great bulk of the work has been done by the United States Engineer Corps, the Los Angeles County flood-control district, and the county of Los Angeles. Both the Corps of Engineers and the flood-control district have completed large structural works and are involved at present in extensive construction programs. A nonstructural activity in aid of flood control is the protection for many years of forest cover in the

mountain part of the watershed from fire, through administration of the Angeles National Forest by the Forest Service, and in the foothill areas by Los Angeles County and city. The United States Weather Bureau will soon establish a flood-warning service for this area, which, while not a measure of flood control, gives promise of averting some flood damages. The essential facts about these programs necessary to an understanding of the recommended agricultural and mountain programs are set forth in the following summary.

STRUCTURAL WORK ALREADY COMPLETED

Work already completed consists of flood-control reservoirs, debris basins, and channel improvements for the purpose of controlling the passage of floodwaters from the foot of the mountains across the flood plains to the ocean. Some large and important reservoirs have been constructed in the mountains for the dual purpose of flood control and water conservation. Also, approximately 4,000 small check dams have been built in the mountain tributaries by local agencies. Although the work of the various agencies is presented separately, all of the existing and proposed works are interdependent and complementary.

Unless otherwise indicated, all figures [4] are for the Los Angeles and San Gabriel watersheds combined. These watersheds are contiguous and have been treated as one composite watershed by the Corps of Engineers. The source material from which figures are drawn does not completely separate the two watersheds, but by far the larger part of the investment for control is in the Los Angeles watershed.

WORK OF THE LOS ANGELES COUNTY FLOOD-CONTROL DISTRICT

The Los Angeles County flood-control district was organized under authority of a State law enacted in 1915. The district prepared a comprehensive plan in accordance with which nearly all major flood-control and conservation projects were constructed until 1935. The most important exception was the Los Angeles diversion channel through the city of Long Beach, which was constructed jointly by the district and the Federal Government at a cost of $3,000,000. Since 1935 permanent improvements for flood control have been prosecuted largely by Federal agencies with active cooperation from the district, which assumed partial responsibility for securing rights-of-way and for maintenance.

Improvements made solely by the district include 12 flood-control dams, 2 flood-control and debris storage basins, 1 diversion dam, many miles of channel improvement, several debris basins, and several water spreading grounds. The total expenditure (including expenditures for maintenance and operation) to December 1, 1939, was approximately $68,800,000 of which about $11,000,000 was for the maintenance and operation and $57,800,000 for construction. Of the money spent on construction about $2,400,000 was for temporary work and $55,400,000 for permanent investment.

[4] All figures refer to status as of January 1, 1940, and have been taken from the report submitted by the U. S. Engineer office at Los Angeles, on the Los Angeles and San Gabriel Rivers, dated February 5, 1940.

WORK OF THE COUNTY ENGINEER'S OFFICE

Prior to 1933 the county engineer's office spent about $6,800,000 of local funds. During 1933–35 this office spent an additional $270,000 sponsoring expenditure of $410,000 by R. F. C., C. W. A., and S. R. A. (State relief administration). From October 1935 to January 1940, the county engineer's office expended $900,000 sponsoring W. P. A. expenditures of $10,400,000. Thus, this agency has spent $7,970,000 of local funds and $10,810,000 from other sources, or a total of $18,780,000. The improvements installed were principally storm drains.

WORK BY THE UNITED STATES CORPS OF ENGINEERS

Prior to 1935 participation by the Corps of Engineers was for the purpose of improving navigation. In May 1935 flood-control funds were made available to the Corps of Engineers under the Emergency Relief Appropriation Act of April 8, 1935. This money was used to provide storm drains, permanent channel improvements, debris basins, and one flood-control and debris-storage basin. Additional allotments followed until the total expenditure under emergency relief appropriations reached $4,976,000 from local funds and $15,764,000 from Federal funds, or a total of $20,740,000.

The existing project of the Corps of Engineers.—The Flood Control Act of June 22, 1936, and subsequent amendments authorized the Secretary of War to proceed with construction work for flood control on the Los Angeles and San Gabriel Rivers, and Ballona Creek. This legislation authorized the existing flood-control project of the Corps of Engineers at Los Angeles. Work done or proposed as a part thereof constitutes the existing project. Portions of it are completed, other portions are under construction, and other units are yet to be started.

The estimated total cost of the existing project for the Los Angeles River and Rio Hondo Basin is $68,489,000, and for the total project, including the San Gabriel River and Ballona Creek, $82,541,000. This is in addition to work done prior to the existing project by the Federal Government through the Corps of Engineers and W. P. A. as outlined in the preceding section. Among the larger items in the Los Angeles project is the Hansen Flood Control Basin to cost $10,380,000; the Sepulveda Flood Control Basin to cost $6,821,000; and improvement of the Los Angeles River through the urbanized area to cost $45,068,000. Total expenditure to January 1, 1940, on the existing project is $37,500,000.

WORK OF THE CITY OF LOS ANGELES

Prior to 1933 the city had expended on 522 miles of storm drains within city limits the sum of $26,900,000, all from local funds. During 1933–35 the city spent $600,000 from local funds to sponsor $3,900,000 from R. F. C., C. W. A., S. E. R. A. (State relief), and L. A. R. A. (county relief). From October 1935 to January 1940 the city spent about $1,900,000 sponsoring W. P. A. construction to the extent of $20,800,000. The city has therefore expended about $29,400,000 local funds and $24,700,000 from other sources, a total of $54,100,000.

WORK BY OTHER CITIES

The cities of Glendale, Pasadena, and Long Beach spent about $2,200,000 prior to 1933, and smaller cities spent lesser amounts. Totals are not available, although it is estimated that, collectively, the various cities have spent about $3,200,000 of local funds and $4,700,000 Federal funds, or a total of about $7,900,000.

The total of all expenditures up to January 1, 1940, by all agencies other than the Department of Agriculture is shown in table 3.

TABLE 3.—*Summary of expenditures on the Los Angeles and San Gabriel Rivers to Jan. 1, 1940*

Agency	Local funds	Other funds	Total funds
Los Angeles County flood-control district	$68,800,000	$500,000	$69,300,000
Los Angeles, city of	29,400,000	24,700,000	54,100,000
Los Angeles County engineer	7,970,000	10,810,000	18,780,000
Other cities	3,200,000	4,700,000	7,900,000
Corps of Engineers (relief)	497,600	15,764,000	20,740,000
Corps of Engineers (existing project)		37,500,000	37,500,000
Total	114,346,000	93,974,000	[1] 208,320,000

[1] It is estimated that $93,000,000 of this total is for the Los Angeles and Rio Hondo watersheds.

OTHER EXPENDITURES BY COUNTY AND CITY

In addition to the expenditures listed in table 3 for direct flood-control structures, considerable sums have been spent by the Los Angeles County Department of Forestry and Fire Warden and by the Los Angeles City Fire Department for the prevention and suppression of brush fires on foothill lands lying outside the national forest.

The present capital investment of the county for this purpose is approximately $337,000. The city fire department maintains a mountain division for brush-fire control.

PROPOSED EXPENDITURES BY THE CORPS OF ENGINEERS UNDER THE GENERAL PLAN

To the framework supplied by the earlier work of the county and city, and the later work under the existing project of the Corps of Engineers, the corps has added new items of improvement considered economically justified at this time in the Los Angeles and San Gabriel watersheds, including Rio Hondo and Ballona Creek. This revised or enlarged plan includes the uncompleted portion of the existing project and such extension of it as is considered advisable. It is called the general plan.

The estimated cost of the general plan, including completion of the existing project, may be broken down as follows:

To complete existing project	$45,041,000
Extension of existing project	185,600,000
Total new work proposed	230,641,000

Of the cost of extension of the existing project about $93,222,000 is for the Los Angeles and Rio Hondo, and about $92,378,000 is for the San Gabriel and Ballona Creek.

SUMMARY OF PAST AND PROPOSED EXPENDITURES FOR FLOOD CONTROL

Thus, the total past and proposed expenditures for the Los Angeles and San Gabriel watersheds will total over $438,961,000. This includes $208,320,000 spent prior to January 1, 1940, and $230,641,000 proposed to complete the general plan after January 1, 1940. As nearly as can be estimated $219,000,000 of this total is for the Los Angeles and Rio Hondo. This expenditure will provide all the downstream flood-control works recommended at this time. This entire sum is being invested to take care of accumulated floodwaters; it involves no treatment whatsoever of the watershed to reduce run-off or silt and debris movement from the watershed into the drainage system, as provided for by the Flood Control Act of 1936.

PREVIOUS WORK BY DEPARTMENT OF AGRICULTURE

It has been pointed out that the area now embraced in the Angeles National Forest was originally withdrawn from the public domain and designated as a Federal forest reserve for the purpose of protecting the watersheds of various southern California streams including the Los Angeles River. Protection of the native forest cover from fire has been the chief element of watershed protection. It is also the primary requirement in aid of flood control. Consequently, past expenditures for purposes of protecting the forest cover in the headwaters of the Los Angeles River from fire have in effect been expenditures in aid of flood control. It is not possible to determine precisely the sum of all investments for fire-control purposes covering the entire period since the area was placed under forest administration, but the value at the present time of fire-control facilities in that portion of the Angeles National Forest lying in the Los Angeles watershed is estimated at $2,180,000. This figure includes fire roads, trails, telephone lines, look-out towers, fire-crew stations, fire-fighting trucks, and other miscellaneous fire-control facilities. It does not include the additional cost of fire suppression since the forest was established, nor does it include the annual operating cost of the fire-control staff and equipment of the national forest.

A considerable additional outlay for fire-prevention has been made during the past several years in the form of presuppression work including such things as the removal of standing dead trees and the clearing of inflammable growth from public roads in hazardous areas. This work has been done with the help of the C. C. C. and W. P. A., and estimates are not available.

PROPOSED PROGRAM OF THE DEPARTMENT OF AGRICULTURE IN AID OF FLOOD CONTROL

The program proposed by the Department of Agriculture does not conflict with or substitute for any elements of the downstream system of reservoirs, debris basins, and channels now installed or proposed for installation by other agencies. It is essentially a program for watershed treatment and deals with the land surface and small waterways rather than with accumulated waters and large channels.

This program may be divided into two broad phases. One phase deals with the mountain area and a second phase with the agricultural

area. The mountain program involves four groups of treatments: (1) Fire control for protection of cover; (2) improvement of the vegetative cover; (3) road improvements to reduce bank erosion; and (4) improvement of mountain channels. The agricultural lands program involves two lines of treatment: (1) Measures and practices on agricultural lands to reduce run-off and erosion; and (2) construction of debris basins and channels to protect agricultural land.

The benefits that will result from the integrated installation of these six broad groups of measures fall into eight general divisions: (1) Reduction of direct damage to property by water and debris and from inundation, (2) reduction of silt and debris deposition on public and private properties, (3) conservation of water, (4) reduction in property loss by fire, (5) reduction in fire suppression costs, (6) reduction in costs of road maintenance, (7) protection and extension of mountain recreational areas, and (8) soil-conservation benefits.

Plan for Mountain Lands

The foothill and mountainous portions of the Los Angeles watershed comprise 363 square miles, or about 43 percent of the watershed area, and of this area 272 square miles are within the boundary of the Angeles National Forest.

The unstable geological structure of the mountain lands, the steep slopes, high altitudes, and ever-present fire hazard make effective treatments of the mountainous and upper foothill areas essential to a comprehensive flood-control program for the whole watershed.

The lower or foothill areas, which surround the San Fernando Valley and extend along the south front of the San Gabriel Mountains, are covered with low shrubs and herbs. The cover on the mountainous and rougher foothill land consists largely of a dwarf natural forest known as "chaparral." The present chaparral cover is the result of site and climatic conditions intensified by recurring fires which have swept through these mountains during past centuries and replacing real forests with brush. Most of the canyon bottoms are occupied by woodlands of sycamore, alder, laurel, maple, and live oak, which have survived repeated fires. Conifers are largely confined to altitudes above 4,000 feet except on northerly slopes and canyon heads where they descend to lower levels.

The extreme relief and rugged topography of the San Gabriel Mountains is due to a geologically recent uplift along major fault lines which have largely determined the present pattern of dissection by deep canyons. Weathering of the crystalline rock mass of the San Gabriel Range is rapid, but the soil mantle produced thereby is shallow and averages only a foot in depth. There are many bare-rock exposures. Soil creep down the steep slopes and rapid erosion when the soil is exposed by fire prevent deep accumulation of soils in place on the mountainsides. During prolonged storms landslides often occur even on densely covered slopes when the slope soils are saturated.

Periodic scour and deepening of mountain channels by flood flows accelerate erosion of the side slopes. In the upper reaches the channels are narrow and V-shaped but become wider and less confined in the lower reaches where the debris deposits build up in some cases to a depth of 50 feet.

During periods of major flood, slope erosion from the sparsely covered or recently burned mountain sides combines with material from unprotected road slopes, and with the accumulated material in the channel ways, to produce debris flows of great volume and violence. The material swept down out of the canyons in this manner descends upon agricultural and residential lands, causing a variety of damages by deposition on roads, streets, cultivated lands, and in channels and reservoirs. It frequently causes interference with the functioning of established channels on the debris cones or the alluvial washes, resulting in destructive diversion of the flood flows into developed areas.

Approximately 6 percent of the mountain land is eroding severely, 38 percent is eroding moderately, and 56 percent is eroding only slightly, under present conditions. Erosion rates vary from very low to extremely high. Recently burned watersheds when visited by heavy rains have yielded up to 150,000 cubic yards of debris per square mile during a single storm. From investigations in the nearby San Dimas Experimental Forest, and analysis of the records for various reservoirs and other catchments, it is estimated that the average rate over the entire San Gabriel Range within the Los Angeles River watershed has been approximately 3,500 cubic yards per square mile per year. The records on which this estimate is based cover periods up to 20 years.

An average figure per unit area per year for such a phenomenon as erosional-debris movement is likely to be misleading when the range is so wide that an area with 50-year old cover yields less than 100 cubic yards per square mile per year during years of normal rainfall, and a newly fire-denuded area upward of 100,000 cubic yards per square mile during a single storm. The erosion rates in mountain areas are more directly related to cover conditions than they are to rainfall. As the vegetation in a burned area recovers, the erosion rates gradually decrease, but for 20 to 30 years following a severe burn high rates of erosion are to be expected in the absence of corrective treatment. Naturally they are highest during prolonged and intense rainstorms.

MEASURES RECOMMENDED FOR MOUNTAIN AREAS

It is clear that such a situation requires treatment on a broad scale and of a complete and balanced character. Therefore a plan has been prepared for work of appropriate magnitude, variety, and intensity. There are four essential parts to the program, each supporting and essential to all others. These parts or remedial measures are described individually in the following sections. They are, in the logical order of presentation, as follows:

(*a*) Fire control for protection of cover.
(*b*) Improvement of vegetative cover.
(*c*) Road improvement to reduce bank erosion.
(*d*) Improvement of mountain channels.

FIRE CONTROL FOR PROTECTION OF COVER

Foresters long have recognized the fire problem of the Southern California Mountains as one of the most critical in the United States, because of adverse climatic conditions, high risk from intensive public use, presence of many high-tension transmission lines, highly inflammable cover, rapid rate of fire spread, rough terrain, and many other factors. These factors are responsible for classifying much of the San Gabriel Mountain Range within the zone of highest rating in the United States in difficulty of fire control. People of adjacent communities are for the most part thoroughly aware of the seriousness of the fire hazard and, in general, they cooperate very well in observing essential precautions with fire. The general public, however, is still largely unaware of the high fire hazards in this area and of the close relation between fire and flood.

From the viewpoint of flood control the chaparral cover is regarded as the main defense against excessive erosion and the formation of debris flows. Thus, although the chaparral has little commercial value for timber or other wood products, it has values for watershed protection and debris damage prevention which make its maintenance imperative.

The first efforts toward fire control by the Federal Government were made in this area in 1892, when President Harrison established the San Gabriel Reserve of 1,500,000 acres "primarily for the purpose of watershed protection and the improvement of water-flow conditions." Subsequent administration of this area represented the first Federal effort for fire control. In 1919 a county forester and fire warden was appointed to develop protection against fires in the foothills and on the Los Angeles County land outside the area protected by the Forest Service. At about the same time local ranchers and water companies organized the Angeles Forest Protective Association to serve as an auxiliary to the Federal and county forces in supplying men and equipment during large fires.

The entire procedure of forest-fire control, including prevention, detection, and suppression, is dynamic, not static. Constant research and reappraisal of methods and results are yielding continued improvements in both. Even while the departmental flood-control survey of the Los Angeles watershed was under way, the Forest Service was engaged upon a fire-control replanning study for the national forests of southern California, including the Los Angeles watershed.

Fire-control accomplishment is commonly expressed in terms of average annual burned area in acres, and in percentage of total protected area. In the past, in the Los Angeles area, the objective has been an "allowable burn annually" of one-half of 1 percent of the total protected area of 349 square miles, or 223,300 acres. At the present time the actual annual percentage burned is 0.85 percent for the entire protected area, and 1.52 percent for the high hazard frontal slopes facing the valley to the south. The present organization is able to obtain its objective of 0.5 percent only during ordinary years. During dry years and periods of extremely bad fire weather the risk of losing control of a small fire and having it develop into a conflagration is very high. In view of the tremendous damages and frequent loss of life, which have been caused by debris flows from large fire-denuded areas, adequate protection in aid of flood control requires reduction of the

average annual burn to 0.2 percent of the protected area. This would mean a reduction of the area burned annually from 1,831 to 447 acres per year in the mountains of the Los Angeles River watershed.

The improvements recommended to effectuate this degree of fire control are aimed not only at reducing total annual acreage of burn but also at holding each fire to the smallest possible area. If the total annual burn of 0.2 percent is made up of several small burns scattered over the watershed, the resulting flood-debris damage will be negligible compared to what it would be if the whole annual acreage were in a single burn.

General features of fire-control plan.—There are six interrelated components of a properly balanced plan of fire protection. They are as follows:

1. Prevention, through control of occupancy.
2. Detection, through more complete lookout service.
3. Speed of attack, through better roads and equipment.
4. Rapidity of control, through adequate facilities and personnel.
5. Safety, through better organization and water distribution.
6. Dependability, through better trained permanent personnel.

1. Efforts to prevent fire are aimed at reducing the number of man-caused fires through public education, regulation of travel, patrolling, and fire-hazard reduction in critical areas. Under certain regulations of the Secretary of Agriculture it is possible to close to public use certain critical areas of the national forests during periods of extreme fire hazard, but the prerogative is used sparingly because of its drastic nature. In some of the most critical areas closure is at present impossible because of the existence of private lands, power lines, and water systems, which carry rights of ingress and egress. Similar closures by county and city officials on much of the wild land under their jurisdictions are impractical because of the many public thoroughfares and much private property. There are 34 major entrances to the Angeles National Forest alone on roads legally open to the public. Therefore, while all possible effort is made to lower the occupancy hazard, it is too much to expect that the problem of man-caused fires will be solved through closure.

The record of fires in the protected area of the Los Angeles River watershed from 1931 to 1938 is shown in table 4.

TABLE 4.—*Number of forest fires, by size and by origin, for the Los Angeles River watershed, 1931–38*

Origin of fires	Number of fires, by class			Percent of all fires
	Fires up to 10 acres	Fires on 10 acres	All	
Smokers	48	4	52	46.4
Debris burning	12	1	13	11.6
Building	11	1	12	10.7
Campers	4		4	3.6
Automobilists	3	1	4	3.6
Power lines	1	1	2	1.8
Industrial	1		1	.9
Incendiary		1	1	.9
Lightning	11		11	9.8
Miscellaneous	12		12	10.7
Total	103	9	112	100.0

2. Effective detection of forest fires is dependent upon and proportionate to an adequate system of lookouts, communications, and trained personnel. There already exists a reasonably complete installation of lookouts, so placed that they command the maximum of area where the incidence of fires is greatest. No additional lookouts are proposed. Current research is concerned with improving detection in hazy weather and with increasing the speed and accuracy of locating fires. The detection system and the rating of fire hazard has in fact been developed by the local units of the Forest Service as a part of its normal program of improvement, and little or no cost to flood-control funds is anticipated for these elements of the fire-control program.

3 to 6. The other four items—speed, accuracy of attack, safety, and skill with respect to personnel—are so bound together that they cannot be profitably analyzed independently of each other. Achieving them is largely a matter of equipment, facilities, and training, which requires as large a proportion of permanent employees as possible in order to capitalize on experience and reduce to a minimum failures of the human link in the chain of control. Consequently, these four items are combined in the analysis which follows. The program calls for the expansion of existing facilities to meet the requirements of the new standards of control. Table 5 indicates the nature and scope of the additions needed to accomplish that end.

TABLE 5.—*Investment in existing and proposed fire-control measures in Los Angeles watershed*

Class of fire-control facilities	Investment of U. S. Forest Service		Investment of Los Angeles County Forestry Department		Investment of Los Angeles city [1]
	Existing	Proposed	Existing	Proposed	Proposed
Roads	$1,614,733	$2,152,129	$176,718	$39,104	$113,225
Trails	98,283	63,679	7,255	6,806	
Administrative units	87,563	376,938	37,444	3,298	8,775
Water developments	14,277	12,306	11,102	1,977	3,489
Firebreaks	223,935	39,524	64,445	750	8,848
Communications	108,929	23,300	12,105	2,500	
Miscellaneous	33,000	220,875	23,958	57,798	6,000
Total	2,180,720	2,888,751	333,027	112,233	140,337

[1] No record available on special investments to date by Los Angeles city for brush-fire control.

The cost of the proposed additions to existing installations on federally owned land will be paid from flood-control funds. For similar necessary additions on county, city, and private lands, one-half the cost of installation will be paid by the Federal Government out of flood-control funds and one-half by the local agencies. In addition local agencies will be expected to furnish all necessary rights-of-way on such lands.

Roads.—About 308 miles of new fire-protection roads will be necessary to obtain a 5- to 15-minute coverage (elapsed time between discovery and attack). These roads are so located as to obtain the best average penetration of risk zones by water-tank trucks and men, and to tap the extensive firebreak system at as many points as possible to permit quick access to them when required.

These roads are essential also to safeguard the lives of men on the fire line. Forest-fire fighting, always dangerous, is extremely so in the chaparral-covered mountains of southern California. The spread of fire through the brush is so rapid that the most careful strategy and tactics are required at all times to prevent loss of life during suppression activities. From this viewpoint the mileage of proposed new fire roads must be regarded as conservative.

Trails.—About 71 miles of additional foot trails are needed to facilitate entrance to and coverage of areas into which it is not necessary or feasible to construct roads or to serve as connecting links between roads, firebreaks, and other facilities. The development of contour trails at vertical intervals of a few hundred feet in the San Dimas experimental forest has demonstrated the value of such trails in speeding up the attack and eliminating the risk of entrapping fire fighters. This is particularly important on steep slopes where flank attacks must be made on fires.

Administrative units.—An administrative unit is a fire-crew station comprising a dormitory or mess hall for a fire-truck crew of from 6 to 10 men, and other buildings such as a garage for the truck, equipment shed, or warehouse, and incidental features such as facilities for water supply, etc. These units, of which 43 are required, are to be located at strategic points along the roads so as to gain the greatest advantage from careful articulation of the proposed new fire roads, the existing fire roads, and the existing highways. In some cases the location will be affected also by the degree of fire incidence so as to make access to highly hazardous areas especially rapid.

Water developments.—An important item of fire-control strategy is the development of local water sources and the installation of storage tanks at frequent intervals along the mountain roads for the refilling of fire-fighting tank trucks (pumpers). Numerous water stations have been developed along streams accessible from paralleling roads by the construction of a small reservoir or water hole or a box or pool in the stream bed to facilitate water intake. On slopes and ridges, roadside storage tanks of 5,000 to 10,000 gallon capacity are kept filled from springs, rain catchment surfaces, or by hauling water to them. The recommended additions to this system are so designed that all tank trucks will be able to reach a water supply within a travel time of 7½ minutes or less.

Firebreaks are necessary to provide cleared lanes from which backfires can be set, at which fires can be stopped, or along which access to fires for direct action upon them may be obtained. About 20 miles of additional firebreaks are needed to complete the required network of roads, trails, and firebreaks.

Communication includes telephone lines and facilities for a two-way radio system. It will be necessary to complete several proposed telephone trunk lines and to make extensions in order to tie in lookouts, administrative units, and field stations with each other and with headquarters. The radio is already in use demonstrationally and has proven of the greatest value.

Miscellaneous items include the installation of diverse equipment such as fire-fighting tank trucks which carry several hundred gallons of water, other power-driven and manual fire-fighting equipment, blankets and small tools, emergency "caches" of small-crew equipment at strategic points throughout the watershed, etc.

Maintenance.—In addition to the capital investment for fire control shown in table 5, there will be an estimated average annual expense of $298,438 for operation, maintenance, and replacement over the 50-year period. These costs will be met from flood-control funds.

Physical benefits.—The purpose of the improved fire-control program is to intensify fire protection and to prevent accelerated slope erosion as a result of loss of cover from burns. Computations have been made to determine the expected effectiveness of the proposed investment, and reliance has been placed on experimental and observational work in and near the San Dimas experimental forest. The results indicate that under present conditions the average annual rate of erosion from mountain slopes alone, not counting channel scour or road erosion, over the 348 square miles of mountain land in the Los Angeles watershed, is 1,414 cubic yards per square mile. It is estimated that by reducing the area of annual burn this average annual rate will be cut to 565 cubic yards per square mile per year, a reduction of the present rate by 60 percent.

It has been pointed out that debris-flow damage is most severe when fire-denuded slopes are subjected to heavy rains. The larger the burn the greater is the potentiality for damage for a given storm. Adequate fire protection, by swift action in keeping fires small, greatly reduces this damage hazard. There is no way of predicting the occurrence of such sequences of fire and storm, but the past record of frequency and violence of such combinations justifies the making of all possible preparations to prevent the occurrence of large fires.

IMPROVEMENT OF VEGETATIVE COVER

Severe burning so depletes the chaparral cover that artificial measures are necessary to hasten its reestablishment. The exposure of local areas of very shallow or very erodible soil results in conditions under which natural regrowth is practically impossible within a reasonable period. Therefore, if excessive erosion rates are to be reduced, it is necessary to resort to artificial seeding or planting. The amount of such work is held to a minimum, because its purpose is primarily to assist and not to replace natural processes.

The area proposed for such treatment is 10,418 acres. About half of it lies within areas burned within 5 years and half within areas burned from 5 to 20 years ago. Broadcast sowing of common mustard seed is the simplest and cheapest treatment; it provides within a year or two a mulch cover which protects the bare soil, improves conditions of infiltration, and encourages growth of the natural vegetation. At some locations it will be necessary to spot sow seed of hardy native shrubs and herbs such as black sage, white sage, wild buckwheat, and deer weed, and to set out wild cuttings of sprouting shrubs, such as baccharis and elderberry.

Planting will be among the first tasks undertaken in order to improve the cover as quickly as possible. The areas successfully sown will require no maintenance. Mustard will produce voluntary crops for a period of 3 or 4 years, thus producing abundant litter which in turn will encourage natural chaparral sufficiently to assure continuity

of cover. The estimated cash outlay for such recommended work on the Los Angeles watershed is $74,420.

ROAD IMPROVEMENT

Construction of many miles of highways and minor roads in the steep mountain areas has been followed by erosion of the unconsolidated fill slopes. In many locations the drainage is faulty, and the concentrated run-off from cut slopes and travel surfaces over the shoulder of the road causes severe gullying of the fills, and in some instances has caused slippage of great masses of material down the mountainsides and into the channels.

Because of public instance for access by automobile to the recreational and scenic resources of the mountain area, many miles of road have been built under specifications giving inadequate protection to the slope surface on fills. Of the 510 miles of existing roads in the mountain and foothill portion of the Los Angeles River watershed, 131 miles are two-lane hard-surfaced, and 379 miles single-lane unsurfaced roads; 246 miles are Federal, 224 miles are State and local roads, and 40 miles are private roads. Approximately 440 miles are in need of improvement to reduce erosion, and of these 281 miles are recommended for improvement in aid of flood control. Benefits from this treatment are $3.19 for each dollar of cost.

Under existing conditions the average soil movement from the banks of these roads by erosion and sliding is estimated at 764,000 cubic yards per year, or an average for all roads of nearly 1,500 cubic yards per mile per year. Expressed in terms of losses per year per square mile of watershed in the mountain area, it is about 2,200 cubic yards. This is about half as much again as the slope erosion from the steep mountainsides. These estimates indicate that road erosion in a mountain area heavily penetrated with roads can and does reach significant proportions.

The material thus put in motion in a watershed causes damage of various kinds, depending on the location. Frequently gullies are cut or slides started which eventually move much more material than that contributed directly by the road. In several instances such material starting from a road on a slope has overrun highways and campgrounds below it, blocked or burdened streams, and destroyed buildings, walls, and other improvements. Eventually a very considerable portion of it reaches the channels and in due time is discharged from the mouth of the canyon as part of a debris flow.

Investigations started by the Forest Service in 1929 called attention to this problem and led to the development of a technique for road slope stabilization for roads in this area. The first application was made by the Federal Government on forest highways in the San Bernardino and Angeles National Forests. The method has been employed to a limited extent by State and county road-building agencies, but on the whole little progress has been made. Consequently, roads in the area require drastic treatment if they are to be stopped from contributing heavily to the debris problem. The remedial measures proposed are believed to be adequate and the calculations of costs and benefits show them to be economically justified.

Treatment.—The first need is to correct faulty drainage. When surface water which has been contributed from several hundred yards of

paved highway is concentrated and poured over the edge of an earthen embankment it causes great damage. Correction requires either paved channels or gutters, conduits or other adequate means of carrying the concentrated flow to points of release where it can do little or no damage. Another common cause of damage—usually by washout or overflow—is the use of undersized culverts or other drains through the fills. The remedy for this is obvious. Several other less common phases of road drainage trouble require correction. These are considered in the proposed plan of improvement.

After drainage has been cared for it is possible to deal with the slope of the bank. The treatment involves mechanical stabilization by means of staking and contour trenching in combination with imbedded wattling and planting. The lower edge or toe of the slope frequently needs protection either by a toe wall or by a mass of boulders which serve the same purpose, i. e., to prevent the starting and progressive sloughing of the toe of the slope.

The control of surface erosion on the road slopes will be obtained by sowing cereal grains and other quick-growing annuals to gain the soil-binding effect of the roots and the accumulation of litter. Such treatment is not alone sufficient, however, and must be incorporated with or followed by the planting of more permanent vegetation. The best practice is to plant cuttings of willows and other sprouting shrubs or, in some instances, nursery-grown trees or shrubs suited to the locality. This complete technique has been applied on a large scale locally and has proven thoroughly effective.

Benefits.—The improvement of upward of 100 miles of mountain roads of various types in California has demonstrated that slope erosion can be reduced to negligible quantities. The benefits are realized in terms of reduced damages from debris deposition at points apart from the roads and of reduced maintenance costs on the roads themselves. Of a total of approximately 500 miles of mountain roads in the watershed, improvement is recommended on 281 miles at a cost of $1,076,298 for installation and $218,957 for maintenance through the 50-year period. This total cost of $1,295,255 will yield benefits in the amount of $3,744,196 or $3.19 of benefits for each $1 of costs.

Future roads.—In the mountainous portion of the Los Angeles watershed all roads built in the future should conform to specifications which provide for satisfactory control of erosion, on the common-sense principle that a road cannot be regarded as finished until the soil and rock necessarily disturbed in construction have been stabilized or rendered harmless to other values. Hereafter, all roads constructed on the public lands in southern California under the jurisdiction of the Department of Agriculture will be to specifications which provide for control of erosion.

MOUNTAIN CHANNEL IMPROVEMENT

Practically all the debris originating in the mountain area and discharged upon the valley lands is transported by the mountain channels. The amount so transported reaches enormous proportions. Control of this material in the channels is essential to the reduction of damage therefrom.

The material delivered upon the alluvial fans at the canyon mouths may be traced to four principal sources—(1) erosion in areas of de-

pleted cover on the steep mountain slopes; (2) erosion and slumpage from roads which have been improperly constructed or maintained; (3) bank erosion and slides from slopes along the channels due to side-cuttings or undercuttings; and (4) channel erosion due to periodic scour and gradual lowering of the channel bed.

The revegetation of depleted cover and the treatment of mountain roads will go far toward reducing the rates at which erosion debris is fed into the channels, but reduction of debris formation in or along the channels themselves and control of debris movement will require direct treatment in the channels. There are two general objectives—(1) to retard the transport of debris already in the channel and the periodic scouring of the exposed channel bottom; and (2) to reduce sidecutting, undercutting, and landslips due to the action of the stream against the banks.

These objectives will be attained through a carefully integrated system of channel improvements of which the principal feature is a series of masonry barriers or check dams. These are placed in the channels to complement existing natural controls, such as hard-rock ledges at waterfalls and box canyons. Auxiliary features articulated with the barriers include clearing of the channel proper, construction of revetments and deflectors at critical points, toe walls at the bases of slices, and occasional channel changes. Revegetation of construction scars and of slopes, slides, and cut banks actively feeding debris to the stream will be the final step. Sometimes this can be done concurrently with construction, but in many instances this work will have to wait until an angle of relative stability has been reached by the bare slopes against the constructed works or upon the channel deposits above the barriers.

It should perhaps be emphasized that the design of such a system of improvement in mountain canyons cannot be developed from a study of the channel profile alone. A tentative paper plan may serve as a guide, but the final plan must be determined largely in the field where all conditions of side-slope gradient, depth of channel debris, position of natural "controls," foundation, material, etc., can be taken into account. For every reach and bend of a canyon a number of different arrangements of structures might be possible. After considering several arrangements and the relation of each to the contiguous reaches upstream and down, the final pattern should emerge as the one which is most advantageous for that particular reach. Speaking as an engineer familiar with both the European practice and the problems in southern California, Paul Bauman, assistant chief engineer of the Los Angeles County flood-control district, has said:

> There are perhaps few other fields that require as much intuition, engineering judgment, and engineering art, in addition to the fundamental laws governing hydraulic structures, as the design and construction of a check-dam system.

Barriers will be constructed only at points where they will effectively stabilize the channel and will be varied in size, design, and placement to take advantage of and to supplement natural controls.

From study of debris movement and its deposition behind check dams, and larger structures in various parts of the area, it has been determined that in general the gradients to be expected behind the proposed barriers will be about 10 percent less than the existing channel gradients.

The effective height of barriers above the existing stream bed will be from 6 feet to 15 feet. They will be built of bedded masonry, precast blocks or concrete, according to size, design, and location. In some instances an arch type will be used, but usually a gravity section will be employed. All structures will be built with weep holes to permit escape of water. Design and workmanship will conform to accepted engineering standards. The estimated total cost of the structures in place is $25 per cubic yard.

The total volume of material which will be controlled by these structures is estimated at 29,000,000 cubic yards in the 50-year period. The estimated total cost, including associated toe walls, retaining walls, bank revetments, etc., is $3,865,000, indicating an average cash outlay for original construction of slightly over 13 cents per cubic yard of debris material withheld from discharging onto the alluvial cones at the canyon mouths. Further discussion of the operation of the barriers will be found in appendix H–2.

It is proposed to extend the construction work over a period of 8 years. A considerable portion of the expenditure indicated for the first year will be for specialized surveys and engineering analysis and design, and for the purchase of equipment and facilities. Beginning with the second year the expenditure for these items will become relatively small and items for labor and construction materials constantly greater.

Approximately one-half of the total channel improvement work in the mountain area falls upon non-Federal land. One-half the cost of installing this work will be borne by Federal flood-control funds, and local agencies will be required to pay the remainder and to furnish all necessary rights-of-way. Local agencies will be expected also to maintain structures on non-Federal lands.

The Los Angeles County flood-control district is qualified legally and technically either to execute the work on private lands or to negotiate with the Department for the execution of all or any part of it in some mutually acceptable manner.

Work will not be started simultaneously throughout the watershed but will be distributed in such a manner as to deal to best advantage with the various elements involved, such as survey and design, transportation, labor, stream flow and storm conditions, etc. So far as possible, work will be concentrated in a few drainage areas at a time so that construction will be completed in each area before leaving it. This procedure will minimize the danger of losses in the course of construction from the onslaught of severe storms on an unfinished system of structures.

The construction of channel barriers and the associated operations on such a large scale will be new in California, although ample precedent exists in Europe where this method of controlling mountain torrents has been established practice for many years. Accomplishments of this nature in various European countries are described in appendix H–3 (Upstream Flood Control in Europe).

It is appropriate to present here in somewhat more detail than has been given above an explanation of the way in which the barriers and their accessory features operate.

Barriers.—Their function and effects will be as follows:

1. To retard further downward cutting of the channel bed. This will stop further acceleration of the crumbling of side slopes which in

many cases are already steeper than the natural angle of repose of the soil and in some cases too steep to be held by vegetation.

2. To retard debris movement. The barriers will anchor the loose material now in the channel, and will trap up to the spillway levels part of the material still in transit from slopes and upper channels.

3. To raise and widen the channel beds (in consequence of item 2). At strategic points this will provide a base level upon which actively eroding side slopes can come to rest and achieve gradients on which vegetation can become established.

4. To reduce stream velocity. Each barrier acts as a drop or waterfall, reducing the effective gradient of the channel and hence the velocity and erosive power of the water.

5. To reduce the movement of large boulders and rock masses. Concomitant of reduced velocity, this is of special importance in southern California because of the great damage done by such materials.

6. To control the direction of flow or the position of the stream. Through careful design and placement the barrier spillways, in coordination with wing walls, deflectors, and training walls, help to confine high flows to the center or other desired position in the canyon bottom and prevent their reaching highly erodible banks.

The barriers are not intended or expected to stop all movement of erosion debris out of mountain canyons. Normal geological erosion will proceed everywhere, but by arresting the downstream transit of the loose material already accumulated in the channel beds, the barriers will withhold large volumes from conversion into destructive debris flows. This material is not generated by the canyon bed but is accumulated largely by erosion of the mountain slopes. When the channels are periodically scoured by flood flows the process of slope erosion is accelerated until the channels are once more filled to capacity. This type of periodic channel debris movement is called "scouring." The degradation of channels by actual downcutting of the bedrock is known as "gouging." This action is especially rapid in the relatively soft rocks of the much fractured and deeply weathered "San Gabriel Formation," which occupies approximately 24 percent of the mountainous area of the Los Angeles watershed. In this formation the barriers are particularly needed to arrest the gouging of the channel bed during peak flows, and in consequence to slow down the general process of erosion. Their action will simulate that of the hard diorite ledges which form natural waterfalls throughout the San Gabriel Mountains.

Training walls and deflecting works will be used as needed to direct the stream away from highly erodible banks. Retaining walls will be used to give footing to raveling slides, which are large contributors to channel debris. Once the toes of such slides are protected it will be possible to complete the fixation of the slides by planting, an operation which is impossible so long as the slide surface is unstable.

Channel clearing involves the removal of logs and boulder jams and occasionally of groups of trees which have sprung up on gravel bars in midchannel. These obstructions often deflect the stream against the canyon sides, causing bank erosion and undercutting of slopes. In a few places channel changes may be necessary for the same purpose.

Once the optimum position of the main channel is established by the structures and rectification work, the growth of vegetation will be encouraged along the channel banks and slopes as an added means of erosion prevention and as an aid in keeping flood flows within the desired limits. On the other hand, the growth of trees in the channel proper will be prevented by periodic removal of volunteer seedlings.

Maintenance of channel improvement.—The type of work herein proposed is relatively new in this country and consequently there does not exist a body of maintenance cost data upon which to draw. Because of the substantial construction to be used, however, it is not expected that the channel structures will require heavy maintenance during the first 50 years of their existence. It will, however, be necessary to inspect each structure after all large storms and after each rainy season. From observation of the performance of similar structures that withstood the floods of March 1938, it is estimated that only minor repairs will be required, but these must be detected and attended to promptly. It is estimated that one-fourth of 1 percent of the total original cost should take care of annual maintenance. This will amount to approximately $12,000 a year for the total proposed channel improvement program in the Los Angeles River watershed, of which the Federal cost will be about $7,000 annually.

Physical benefits of channel improvement measures.—Estimates of the volume of debris that will be controlled by the structures are based on field surveys and include only that material which is now in transit or which, without channel control, will move downstream to reservoirs and the valley within the next 50 years. (The method of estimating the amount of debris movement to be prevented by the proposed work is explained in appendix H–2.) The estimates are believed to be conservative, and it is probable that over the 50-year period a greater quantity of debris than that estimated will be withheld from movement as a result of the channel program. While some of the benefits have been stated in general terms in the discussion of effects, many additional benefits will result from channel control.

Recreational areas adjacent to the channels, which have been damaged by past floods, will be restored and protected, and additional areas will be made available by elimination of the flood hazard. Much damage to roads, bridges, and utilities by impact and deposition of debris will be prevented. Residences, resorts, stores, and cabins along the canyon sides will benefit directly from channel control by the reduction of debris flows having great powers of destruction. Aesthetic values in the canyon bottoms will be increased as a result of the controlled growth of trees along the channel sides. Agricultural lands will be protected from periodic deposition of boulder debris during floods. Water conservation will be aided by the deposition of clear water on the spreading grounds.

Previous efforts at mountain channel improvement on the watershed.—Within the past 25 or 30 years upward of 4,000 "check dams" of various types have been constructed in the canyons of Los Angeles County. Of this number upward of 2,000 structures are still intact and functioning as originally planned; the remainder have been damaged in various degrees or destroyed altogether. In consequence of this record much controversy over check dams has occurred in engineering circles in California and opinion is still divided on the subject.

The majority of engineers familiar with the problem incline favorably toward the use of the barrier method provided the structures are substantially built on sound engineering principles and the work is designed and constructed as a complete integrated system for each stream.

In the absence of adequate hydrologic data for the mountain area the designs for the early structures were often inadequate. Today, in the light of further research and more abundant hydrologic information, the designs can be confidently adjusted to the requirements. Whereas most of the early structures were built with either dry rubble or rather small loose rock bound together in mattress fashion with woven wire, the proposed program will employ only substantial masonry, concrete, and masonry-capped structures. In some sites steel-sheet piling capped with concrete may be used. All structures will be provided with weep holes to allow free drainage.

The method of channel control by barriers is not, however, without successful precedent in Los Angeles County. During 1935 and 1936 a small project of this type was executed in a portion of Brand Canyon on the southwest slope of Verdugo Mountains directly north of the city of Glendale. Approximately 51 percent of Brand watershed is embraced in Brand Park belonging to Glendale, and the project was sponsored by that city. Engineering design for the structures and planting plans for road slopes and slides were supplied by the Forest Service. None of the permanent structures has failed. (This project is submitted in appendix H–1.)

EXECUTING THE MOUNTAIN PROGRAM

Responsibility for the remedial program in the Angeles National Forest will be placed in the Forest Service. That agency, through the regional forester's staff in San Francisco and the forest supervisor's staff in Los Angeles, already has engineering and other technical personnel capable of developing the program in detail and of carrying it out.

The responsibility for work on non-Federal lands, including both municipal and private, will be determined by arrangement between the Forest Service and the local agencies. The Los Angeles county flood-control district and the county forestry department will be the agencies chiefly concerned, especially with regard to channel improvement and fire control respectively. To a smaller extent in fire control, the city fire department will be involved: In the road-improvement work, the county engineer's office and the State division of highways will be involved. All of these agencies have cooperated with the Department through the Forest Service for many years and the required cooperation in the proposed program can be expected to proceed satisfactorily.

Farm Land Improvement and Treatment

Approximately one-fourth of the Los Angeles watershed is devoted to agricultural use, and much of this use is of great intensity. A considerable portion of the total area to be treated is adjacent to urban and suburban property which is very susceptible to damage from eroded material and water flow originating on the agricultural land.

It will not be necessary to treat every acre of agricultural land to attain the objectives of the program. Some local areas are already in satisfactory condition, notably the very large acreage of alfalfa. Some areas are partially in good condition and therefore will not require full treatment, and some areas, because of probable early conversion to suburban use, should not be treated. The conclusion from the field survey is that all of these items combined account for a deduction of about 13 percent from the cultivated area. Therefore, the 111,366 acres listed as "requiring treatment" represent 87 percent of the total area devoted to agriculture. A further deduction of 10 percent, to allow for failure of some farmers to cooperate in the program, has been made in calculating costs and benefits, which brings to 100,229 acres the actual area which the Department expects to help farmers to treat. Table 6 classifies the agricultural land according to the need of treatment.

TABLE 6.—*Agricultural land classified according to treatment required*

Flood source area [1]	Land needing treatment			Land needing no treatment			Grand total
	To be treated	Not to be treated	Total needing treatment	Alfalfa	Other	Total	
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
1	48,689	5,410	54,099	6,304	1,626	7,930	62,029
2	14,556	1,617	16,173	2,253	160	2,413	18,586
3B	4,567	508	5,075	0	0	0	5,075
4B	1,089	121	1,210	0	761	761	1,971
5	3,185	354	3,539	0	58	58	3,597
6	852	95	947	0	0	0	947
7	1,164	129	1,293	0	0	0	1,293
8	11,088	1,232	12,320	563	1,005	1,568	13,888
9	15,039	1,671	16,710	3,302	340	3,642	20,352
Total	100,229	11,137	111,366	12,422	3,949	16,371	127,738

[1] See map of Los Angeles watershed attached.

SOIL-LAND USE RELATIONSHIPS

The character of the soil is of the utmost importance in relation to erosion, infiltration and run-off when land use and changes in land use are considered. The following paragraphs describe briefly the important soil-land use relationships for the agricultural area. A further description is contained in appendix K.

The bench lands are used for orchards, grain, or grazing. Here the topsoil is loose and friable and the subsoil is compact, old alluvial material. The infiltration rate is very low, and the erodibility very high, with advanced sheet erosion and some trench gullying. About 15 percent of the cultivated land is of this type.

The upper valley lands are frequently intensively cultivated to orchards and vineyards. They are composed of recent alluvial deposits with little or no profile development. These soils have a sandy or friable surface texture and are relatively deep, so that with proper cover and culture, very little erosion and run-off occurs. However, when unprotected, as usually is the case, this soil disintegrates easily and erosion losses may be very high. From the point of view of the program, this soil is the most important in the watershed since it is the most intensively cultivated and has a high erosion rate.

About 70 percent of the cultivated land is of this type. It is the major contributor of silt.

The lower valley lands are very much like the upper valley lands except that the slopes are usually less, and the depth of soil is greater. These lands, which occupy the center of the valley area, do not present a serious erosion or run-off problem if provided with suitable cover, but otherwise, even though the slope is gentle, they do produce great quantities of fine silt which washes onto adjoining roads and suburban lands. About 15 percent of the cultivated area is of this type.

ERODED MATERIAL AVAILABLE FOR DEPOSITION

The amount of eroded material which is estimated to move off the entire cultivated area (nearly all as sheet erosion) to cause off-site damage, varies from practically none to as high as 9,000 cubic yards per square mile per year for large areas. There are many isolated instances of extreme erosion rates for small areas. Over the area to be treated the weighted average rate is about 1,300 cubic yards of eroded material per square mile per year. This figure does not include material which moves about on the property upon which it originates, but only that portion of total soil movement which leaves the property and creates damage or expense of a community character. Neither does it include material kept from agricultural land by debris basins at the mouths of the minor frontal canyons.

Different types of land-use-slope areas vary widely in the amounts of eroded material which they yield. Table 7 shows the factors and rates used in calculating silt movement from agricultural land. The method of calculation is fully developed in appendix K.

TABLE 7.—*Estimated annual production of eroded material moving from agricultural land into other areas, according to slope and land-use classifications*

Type of land use	Average annual rates in cubic yards per square mile per year				
	On A slope 0 to 3 percent	On B slope 3 to 10 percent	On C slope 10 to 25 percent	On D slope 25 to 40 percent	On E slope above 40 percent
Citrus and avocados	340	2,100	3,000	5,250	7,500
Deciduous fruits	300	1,500	2,250	3,750	6,000
Cereal hay and grain	750	2,250	4,500	9,000	----------
Row crops	340	670	5,250	9,000	----------
Diversified crops	340	670	5,250	9,000	----------
Grassland	30	95	225	600	950

FLOOD AND STORM DAMAGES TO BE REDUCED

Every storm of sufficient magnitude to cause run-off results in the movement of debris, sand, and fine silt from agricultural land onto streets and roads. Storms of greater magnitude move progressively larger volumes. Consequently, during a 50-year period without application of corrective measures, great quantities of silt, sand, and debris will be moved from the agricultural land to locations from which it must be removed at great expense, or where it remains to cause depreciation of the property involved. Reduction of this expense or depreciation loss is a direct benefit to the community at large and is referred to as a flood-control benefit. Such a benefit might be called

an off-site benefit since it accrues to others than the owners or users of the land on which the measures are applied.

The treatment required to reduce soil movement from agricultural land benefits the land itself by saving topsoil and helping to maintain fertility. This is also a community benefit, but primarily it is a benefit to the agriculturist whose land is treated. Accordingly, from the standpoint of allocation of costs based on benefits, it is referred to as a "conservation" benefit, and major contributions in meeting costs are expected from land owners. Such benefits might be called on-site benefits since they accrue to the owners of land on which the measures are applied.

In a similar way, reduction of run-off creates both conservation and flood-control benefits. A reduction in damage to property by flood violence caused by run-off or silt or debris movement from agricultural lands may likewise be classified according to its location—whether on the land where the run-off or silt originates or somewhere else.

The primary objective of the proposed remedial program is run-off and water-flow retardation and soil-erosion prevention for flood-control purposes, and flood-control benefits are the basis of justification for the expenditure of flood-control funds. A secondary objective is to accomplish the maximum possible conservation benefits to the agricultural land. Other flood-control or community benefits also accrue, through increases in ground-water supply, etc.

GENERAL PLAN OF TREATMENT

The measures proposed for application to agricultural lands in the valley and lower foothills consist of two types: (1) Changes in the use and cultural treatment of land, and (2) construction of debris basins, channel improvements, drops, check dams, and so on, for the purpose of protecting agricultural land from flood and debris flows originating above it, or to facilitate improved agricultural practices on it.

LAND USE IMPROVEMENT MEASURES

The proposed program requires the application of proven soil conservation type practices involving: (1) Cultural treatment, (2) changes in land use, (3) minor construction on individual properties, (4) community-type construction, and (5) debris basins and channel improvements. These measures will be adopted and applied so as to produce the maximum possible community or flood-control benefits; however, they will also produce important local benefits in the interest of the farmer whose land is to be treated.

1. Cultural treatment involves the use of simple mechanical practices intimately associated with normal farm operations. It includes correct tillage methods, contour ridging and ditching, terracing, basin listing, and improvement of irrigation practices. In general, although the effect on the control of silt movement and run-off is marked, the installation and maintenance of such practices is not expensive.

2. Improvements in land use are practical for application on certain areas, and when effectively applied result in a very important reduction in silt movement and run-off. Among these items are the use of green manure and cover crops, rotation of crops, pasture and range

management, tree planting and woodland management, and retirement of land from cultivation.

3. Minor construction work on individual properties includes terraces, terrace outlets, terrace outlet channels, various kinds of check dams and flumes, bank revetments, and diversion channels.

4. Community-type construction includes improvement of channels which traverse several properties, the control of large eroding gullies and the correction of community drainage systems serving several farms.

5. Debris basins and channels. In some places construction of small debris basins and the improving of minor channels will be required to protect agricultural land from flood and debris flows from the minor frontal canyons. A full description of the type of construction proposed appears later in the report.

SPECIFICATIONS FOR PROPOSED REMEDIAL MEASURES

As a basis for determining remedial measures, a careful survey was made of all agricultural land, and maps were prepared showing soil, slope, erosion, and land use. By suitable study and superposition of such maps, the land in use for agricultural purposes was divided into type areas, as for example, "Citrus on a C slope." [1] The final mapping of these areas establishes classifications for the purpose of specifying remedial measures.

Each of these "use and slope types" requires appropriate treatment for reduction of run-off, reduction of silt production and movement, increase of water conservation, and reduction or elimination of local flood damage (such as destruction of or damage to buildings, farm equipment or farm facilities, culverts and other drainage facilities, or by gully formation, channel bank cutting, and deposition). For the Los Angeles watershed there are nine type classifications or groupings of land in agricultural use for which generalized work specifications have been prepared.

1. *Specifications for citrus and avocados on A slopes.*—The principal measures proposed are increased use of cover crops, applications of organic mulches, and contour cultivation. Winter tillage will be discontinued. Summer irrigation furrows will be obliterated at the end of the irrigation season when advisable. Modified basin listing will be inaugurated where needed. Treatment of this type will be applied to 19,626 acres.

2. *Specifications for citrus and avocados on B slopes.*—All areas in this group should be protected by annual or permanent cover crops or basin listing, or by the two measures combined. Steeper slopes will require permanent cover crops or continual use of organic mulches. General conversion to contour tillage and contour irrigation practices will be required. Treatment of this type will be applied to 7,112 acres.

3. *Specifications for citrus and avocados on C, D, and E slopes.*—Groves on these slopes will be protected by complete permanent cover of perennial grasses, legumes, or by continual use of organic mulches. Cultivation considered necessary until permanent cover becomes established will be conducted on the contour. Furrow

[1] Classification of slopes in this report are by alphabetical index as follows:

A slope=0 to 3 percent
B slope=3 to 10 percent
C slope=10 to 25 percent
D slope=25 to 40 percent
E slope=above 40 percent

irrigation, when practiced, will be on the contour and furrows will be left for winter diversion of excess run-off. Treatment of this type will be applied to 1,399 acres.

4. *Specifications for deciduous orchards and vineyards on A and B slopes.*—Basin listing and winter cover crops are especially appropriate measures for this group. Selective use of permanent cover crops and mulches are better adapted to the more impermeable soils. Grade ditches replaced annually will be used where basin listing is impracticable. Cultivation will be conducted on contour. Where irrigation is practiced, furrows will be on the contour and will be left during winter to minimize erosion and retard run-off. Treatment of this type will be applied to 9,032 acres.

5. *Specifications for irrigated row and miscellaneous crops on A and B slopes.*—Irrigated row and miscellaneous crop areas do not produce high erosion rates, yet cultivation and irrigation on the contour, crop rotation, and the plowing under of crop residues will be practiced with a view to decreasing run-off. Basin listing will be installed where suitable on areas not planted to winter cash crops. Treatment of this type will be applied to 30,356 acres.

6. *Specifications for cereal hay and grain on A slopes.*—Correct tillage operations, crop residue management, and a rotation including a leguminous crop for green manure will improve fertility and percolation. Treatment of this type will be applied to 10,545 acres.

7. *Specifications for cereal hay and grain on B slopes.*—Terracing, or contour soil preparation and sowing operations, along with crop residue management, are preferred types of treatment for grain hay on B slopes. Soil building crop rotations should be used. Treatment of this type will be applied to 3,029 acres.

8. *Specifications for grain hay on C and D slopes.*—Limited terracing operations, contour soil preparation and sowing, and crop residue management, will be undertaken on this land. Cover always will be kept on one-third of the area during the critical periods in the late fall or early spring by means of strip cropping or pasture establishment. A larger percentage of this land will be converted to pasture or grass woodland, provided such farm reorganization is economically sound. Treatment of this type will be applied to 1,325 acres.

9. *Specifications for lands in pasture and range use.*—The entire acreage in this group should be subjected to appropriate pasture or range management governing the kind and number of stock and the time and place of grazing. A limited program of seeding, contour furrowing, fence construction, and improved water facilities will be effected. Treatment of this type will be applied to 17,805 acres.

The specifications numbered 1 to 9 are descriptive statements of treatment recommended. For the sake of directness they have been stated in positive language. Of course, the application of these treatments will be entirely voluntary on the part of the farmer who will deliberate with the technicians in drawing up the plan of operation for his land. On some farms the adjustment may be slight, on others more complete reorganization may be necessary. The goal is to secure as complete treatment of the agricultural land as possible in order to obtain the greatest possible degree of erosion reduction and run-off retardation, and to obtain also the maximum conservation of land productivity.

For ease in visualizing the distribution of areas to be treated the acreages are summarized in table 8. All calculations of cost of installation and of maintenance, and all calculations concerning benefits resulting from farm land treatment, are based on the net acreages given in this table.

TABLE 8.—*Acres of agricultural land on which specified flood-control measures are recommended*

Flood source area No.	Acres to be treated under each specification									Total
	Specification number									
	1	2	3	4	5	6	7	8	9	
1	5,996	2,004	582	7,995	13,456	5,247	1,543	864	11,002	48,689
2	4,476	58	0	0	6,618	1,065	559	0	1,780	14,556
3B	732	2,505	139	149	939	40	17	0	46	4,567
4B	115	357	46	0	571	0	0	0	0	1,089
5	461	610	437	0	225	0	0	0	1,452	3,185
6	0	23	0	0	0	0	0	0	829	852
7	35	852	0	0	0	0	0	0	277	1,164
8	4,424	427	195	0	4,959	461	288	0	334	11,088
9	3,387	276	0	888	3,588	3,732	622	461	2,085	15,039
Total	19,626	7,112	1,399	9,032	30,356	10,545	3,029	1,325	17,805	100,229

EFFECTIVENESS OF PROPOSED MEASURES

To evaluate quantitatively the effectiveness of the proposed remedial measures, applied singly and in combination, is extremely difficult owing partly to the complexity of the problem and partly to lack of applicable local records concerning the effectiveness of such measures. After considering published data and local recorded experience, the following general conclusions were drawn with respect to the effectiveness of the more important measures under southern California conditions.

Use of annual or winter cover crops.—It is estimated that if lands normally left without winter cover are provided with a satisfactory cover during practically the entire period of winter rains, the total storm run-off will be reduced by 50 percent and the soil movement off the area by 85 percent.

Use of permanent cover.—Application of a permanent cover, either perennial or volunteer annual, will produce better results than winter cover because of the earlier seasonal effectiveness and the permanent root system. It is estimated that applying permanent cover to cultivated orchards will reduce the total annual storm run-off 67 percent and soil movement from the area 95 percent.

Suitable crop rotation.—Including close-growing leguminous crops in the crop rotation, especially green manure crops for plowing under, will improve the condition of the soil so that it will be able to take up water more readily. It is not, however, possible to evaluate with any precision the effect such improvements in the physical condition of the soil will have on run-off and silt movement under conditions on the Los Angeles watershed.

Contour tillage.—In general, contour tillage by itself is not a sufficiently effective measure to permit generalized quantitative evaluation, but when used as an integral part of the over-all program it

serves to support practically every other remedial measure recommended and makes a positive and very important contribution to the control of erosion and run-off. Its value, therefore, is usually submerged in the values given for the other measures.

Terracing.—Like contour tillage, terracing serves best when used in connection with other measures. Its principal function is to reduce soil movement. No independent evaluation is made for terracing; its effects are submerged or included in the rates established by a combination of measures.

Basin listing.—Under normal rainfall intensities, basin listing or modified basin listing is exceedingly effective when soil and slope conditions are appropriate. For lands for which it is suitable, basin listing, especially when combined with a cover crop, can be counted on to prevent practically all run-off and soil loss except during long continued periods of high intensity rainfall.

Improvement of irrigation practices.—One of the leading causes of soil movement in southern California is improper or careless handling of irrigation furrows. By reasonably inexpensive modification of some irrigation systems, and more careful use of others, the amount of erosion can be reduced up to about three-fourths. Material saving to the farmer will result from more efficient use of water under the modified practices.

Combined effectiveness.—The estimated factors evaluated in the preceding paragraphs were carefully applied to the appropriate acreages to arrive at a total effectiveness for the entire area. Conservatively estimated, the completed treatment on the agricultural lands should result in slightly better than a two-thirds reduction in silt movement from the treated area. In a similar manner, the run-off reduction factors were combined to arrive at appropriate estimates of the probable increase in ground water supplies, of the probable increase in soil moisture, and of the probable reduction of peak run-off during storms of flood-producing magnitude. The greatest effect would occur in the San Fernando Valley where the peak run-off at Sepulveda Reservoir probably would be very materially decreased as a result of increased infiltration rates made possible by the completed treatment of the agricultural land. Not much effect on peak run-off is claimed for any other area, because no other area presents such deep soil and such favorable conditions for large-scale surface treatment.

PROCEDURES AND METHOD OF OPERATION

So far as possible the responsibilities for doing the work of installing remedial measures on agricultural lands in the interest of flood control and the cost thereof will be placed on the farmer or property owner, because the benefits to his land will justify the costs to him. The Federal Government, through expenditure of flood-control funds, will supply technical advice, technical lay-out and supervision, and practical instruction. To an extent depending on the necessities and merits of each case the Federal Government will lend equipment, supply some seeds, planting stock, labor and materials for minor construction.

Construction of debris basins and the improvement of minor channels cannot, because of the character of the work, be handled by farmers. A responsible public agency such as the Los Angeles County

flood-control district or the Department of Agriculture will have to build the basins and improve the channels. Which agency will assume this responsibility will be determined in negotiations between the Department and the district.

Contact agency.—It is impractical for the Department of Agriculture to deal individually with each property owner. Therefore, it is proposed to enlist the cooperation of Los Angeles County through its legally constituted flood-control district, which will function in much the same way as does a soil-conservation district under California State law. It appears from a study of the Los Angeles County Flood Control District Act that in some respects the legal rights and powers of the district are even greater than those of a soil conservation district. An opinion by the office of the Solicitor of the Department of Agriculture indicates that the district is legally qualified to function as desired. Informal advices lead to the belief that the district will cooperate. The advantages of such an arrangement are many, for example:

1. The district has had many years of experience and has valuable local contacts useful in negotiating for rights-of-way. Consequently, such important negotiations could be handled more effectively by the district acting as agent than by the Department of Agriculture acting direct.

2. The district is experienced in collecting flood facts and has at hand a valuable collection of data, which would be of great assistance to the Department of Agriculture. A cooperative technical advisory relationship will be very valuable.

3. It is probable that direct contact between the Department of Agriculture and other local agencies would be more effective if conducted through a mutually recognized liaison agency. The Los Angeles County flood-control district is well qualified by prestige and experience to serve as such a liaison agent.

4. The district can help materially in explaining to local people and local agencies the merits of certain of the new types of measures recommended in the agricultural program.

5. It would be expensive and not entirely satisfactory for the Department of Agriculture to take over the future maintenance of flood-control structures outside of the national forests. The district, which is responsible for maintaining county structures, could assume responsibility for maintaining the structures built by the Department. It has the necessary equipment, facilities, experience, and personnel.

5. After the action program is completed it will be of advantage to continue formal cooperative relationships between the district and the regional offices of the Department. This will permit better collaboration on flood-control problems still unsolved and permit joint participation in hydrologic and other needed studies.

Technical staff.—As nearly as it can be estimated, about 4,500 farm plans and agreements will be required. To handle the technical work of farm planning will require the services of an adequate staff of technicians with their associated clerical workers.

It is planned to complete two-thirds of the total number of agreements (about 3,000) during the first 5 years and the remaining one-third (about 1,500) during the second 5 years. The estimated total cost of the proposed technical staff for developing farm plans is

$244,000, of which about $175,000 will be required during the first 5 years.

Operating relationship between the district, the Department, and the farmer.—It is not possible to establish in detail at this time the exact manner in which it is hoped the Los Angeles County flood-control district will function in connection with farm land treatment. In general, the procedure probably will be as follows: A memorandum of agreement will be entered into between the Secretary of Agriculture and the Los Angeles County flood-control district, under which the district will function as the legal agency for executing agreements with farmers in behalf of the Department of Agriculture.

The local action agency of the Department of Agriculture (Soil Conservation Service) will represent the Department in all technical and operations matters. The Soil Conservation Service will cooperate with the district under the memorandum of agreement, serve as the technical and operating arm of the Department and the district, and handle all the details of preparing farm plans and supervising installation work.

Construction work of community nature.—There will be required, in the direct interest of flood control, the corrective treatment of minor or secondary natural and artificial channels which traverse a number of properties, the cost of which cannot reasonably be charged wholly against any one of them. In such cases the benefits resulting from work on a property will not accrue entirely to that property, but to adjoining properties downstream. This work is defined as work of a community nature.

The intent is to hold the expense of such work to a minimum by requiring as much of it as possible be done by property owners, by local communities, or by other local groups. Involved are such items as gully plugging, channel straightening and clearance, bank revetments, diversions, gathering ditches to establish control of wild drainage, drops, transitions, check dams of the larger type, and so on. For this strictly community type of work, the sum of $150,000 is recommended from flood-control funds for use over the whole agricultural area.

Cooperative installation with farmers.—Many of the proposed remedial measures can be installed and maintained by the farmer at little additional expense to him. Some measures will require expense for installation and some changes in his method of operation, perhaps reducing his current income during the first few years. Under the latter circumstances flood-control funds will be used for certain materials and installations.

Flood-control funds will be used to provide engineering lay-out work and supervision, some construction materials, the loan of construction equipment, the loan of agricultural equipment of certain specialized types, a limited amount of seed and planting material, fencing, and water developments on grazing land, and other items involving service, labor, or materials.

The nature of the installation work is such that on any particular parcel of land, the greatest expense will occur during the first year, followed by a greatly reduced follow-up expense the second year, and development to a maintenance basis in the third year. Beginning with the fourth year all expense will be considered maintenance.

The experience of the Soil Conservation Service in southern California indicates that in order to bring about general and prompt acceptance of the proposed remedial measures—without which the general plan will become greatly diluted and only partly effective—it will be necessary for public funds to supply technical services, materials, and loan of equipment in an amount averaging about $5 per acre, the total not to exceed $565,600.

The measures which farmers are asked to adopt and apply will yield community flood control benefits in excess of $3,700,000, and this sum both justifies and sets the limits to which flood control funds can equitably be used to institute the program. Flood control funds will be used to finance cooperation with the farmers in order to induce them to institute the complete program at an early date.

SUMMARY OF ESTIMATED INSTALLATION COSTS

The cash costs of installation for the various items recommended as parts of the complete plan (excluding debris basins and channel improvements) for the 100,229 acres to be treated (average acre value $738) are summarized as follows:

Technical staff (land use)	$275,000
Community construction	175,000
Land measures (flood control funds)	604,060
Land measures (farmer)	1,120,058
Grand total cost of land measures	2,174,118
Borne by flood control funds	1,054,060
Borne by farmers	1,120,058

MAINTENANCE

The whole cost of maintenance and repair of the agricultural land treatment program will be borne by farmers. For the 50-year period this cost is estimated at $8,898,100.

CONSTRUCTION OF DEBRIS BASINS AND IMPROVEMENT OF MINOR CHANNELS TO PROTECT AGRICULTURAL LAND

When completed, the large-scale construction programs proposed by the United States Engineers and the Los Angeles County Flood—Control District will provide adequate protection from flood and debris flows in all of the streams which require attention from these agencies. However, along the front where the foothills meet the valley there are small streams which neither agency proposes to treat but which are important because of their damaging effect upon local agricultural lands, and in some instances upon valuable institutional or suburban lands.

Unless immediate local relief is given to agricultural areas below the frontal canyons, or along the channels, it will be impractical to carry out an improved land-use program on the agricultural land below. Farmers will not willingly finance flood control remedial measures on their own land and adopt new land-use practices for the public benefit unless they themselves feel reasonably well protected from the onrush of floodwaters and silt flows from above. Some minor debris basins

and some channel improvements are therefore prerequisites for a satisfactory agricultural program in the affected areas.

Consequently, in order to bring about in such areas a program of land treatment in aid of flood control, the Department of Agriculture proposes to cooperate with local agencies in the construction of a limited number of small debris storage dams and in the improvement of some stream channels. This construction will neither duplicate nor substitute for the work proposed by the Corps of Engineers, or that proposed by the Los Angeles County Flood Control District. It will be very definitely a part of the agricultural program to protect properties and values on the alluvial fans from severe local flood and debris damage.

Division of cost of construction.—It is proposed that flood control funds bear one-half the construction costs of such improvements and that local agencies bear the other half of construction costs, furnish rights-of-way, and assume all costs of operation and maintenance.

The exact procedures local agencies will follow in carrying out this cooperative work cannot be fully determined in advance. The proposal is to work very closely with the Los Angeles County Flood Control District with respect to priority, design, rights-of-way, and construction procedure. The district will then be in a position to investigate the conditions on which it and other local agencies will base contributions to the extent of one-half the installation cost and the full cost of rights-of-way.

Actual construction may be by the Soil Conservation Service or by the District, or by some other local agency according to arrangements made at the time. Maintenance and operation will be provided for by formal agreement before construction is undertaken.

Debris basins.—The plan proposed in this report is to give preference in general to "debris storage basins" that provide permanent storage which will become dead when filled, rather than to the ordinary debris basins which require excavation when filled. New storage capacity will be provided by raising the spillway height or building a new dam slightly upstream.

Before work is begun, a thorough joint study will be made of each location by the Department of Agriculture and the Los Angeles Flood Control District, or such other local agency as may join in bearing the cost of construction, to determine which of the two types of storage is more desirable. However, a preliminary study by the Department of Agriculture indicates that the advantages of the storage type of basin justify this design.

Debris storage basins will be located in or near the mouths of the canyons, to provide maximum capacity at least expense. In general, the dams will be of the earth-fill type and will be so constructed as not to create water impounding reservoirs. Their only purpose is to retain silt and debris. In every case, concrete spillway capacity will be provided to take care of a possible flood flow based on the design storm adopted by the Corps of Engineers.

At points where the present annual movement of silt and debris is such that a debris basin is required, it will be constructed at once of sufficient capacity to provide level-full storage for about 25 years at the present annual rate of watershed erosion, or of sufficient capacity to take care of debris from a major flood following a fire, whichever capacity is greater. In due time, the storage capacity will become

so reduced that it will not be sufficient to take care of a major storm under the then improved condition of the watershed. At that time the storage capacity will be restored either by the addition of height or more commonly by the construction of a second low dam immediately upstream and on the fill back of the first dam.

It is proposed to build debris storage basins of sufficient size to form a storage capacity when level full of from 43,000 to 115,000 cubic yards per square mile of contributing watershed. Dams at the base of the San Gabriel Mountains, from Pacoima Wash to the eastern watershed boundary, are all planned for 115,000 cubic yards of storage capacity per square mile. The design capacity gradually grows less for locations following counterclockwise around the San Fernando Valley from Pacoima Wash, until 43,000 cubic yards per square mile is used as a basis of design in the Santa Monica Mountains on the south side of the valley.

These basins will be designed for an average storage life of 25 years at the present rate of deposition before they become level full. All cost and useful life figures are based on level full capacities. These estimates are believed to be conservative because two factors will tend to increase the storage life to perhaps 35 or 40 years. The first factor is the gradual improvement of the watershed cover under the proposed program, and the second is that the debris deposit above the dam will not be level but will slope upward. This will add greatly to storage capacity, and decrease the cost per cubic yard of storage proportionately.

The average effective height of the debris dams from channel to lip of the spillway will be about 18 feet with a maximum of 25 feet. The cost of constructing debris storage, including rights-of-way, will average about 30 cents per cubic yard of level-full storage capacity, ranging from a minimum of 17 cents to a maximum of $1 per cubic yard of storage. For the future additions the cost per unit of new storage capacity should be considerably less than for the original storage. The cost for increasing the height of all dams 25 years hence is included in the total estimated cost of maintenance and operation for the 50-year period.

Design of dams.—The dams are to be of the earth-fill type with crown width, side slopes, and construction all in accordance with generally accepted specifications for design, material, and workmanship. It is anticipated that material near the dam site can be used in practically all cases. For the second lift of the dam, most of the material for the fill can be taken from the basin itself.

Channel improvement.—In come localities a serious problem is presented by minor streams which emerge from minor frontal canyons onto alluvial fans devoted to intensive cultivation or institutional use. Such streams are an ever-present threat to the agricultural land through which they pass and deserve special consideration in flood control operations.

Even though the channel of a stream from a small canyon is well defined the stream may have a highly erosive effect in its course over the alluvial fan, especially if the water is partly desilted at the canyon mouth by a debris basin or by natural deposition. The result is often excessive erosion due either to meandering of the stream, or to undercutting of banks followed by collapse of the side walls, or erosion of the stream bed. Whenever a storm of greater than usual magnitude

occurs, the erosive activity of such streams is very great, and results in great damage along the banks of the channel, and to the agricultural valley lands and drainage system immediately below.

In such situations it may be necessary to build an effective stilling basin, or other similar control, below the spillway of the dam or at the break in grade at the canyon mouth in order to reduce the velocity of the flow at its entrance into the channel. It may also be necessary to install bank protection at some points lower down on the channel where bends or other local conditions tend to promote excessive erosive action.

A different and more hazardous condition exists where a canyon discharges great quantities of debris and silt, and where the channel over the alluvial fan is poorly defined. Under such conditions it is almost impossible to predict with any certainty how much deposition will occur or where it will occur. It is not unusual in such instances for the channel to divert to a new location and force its way through highly developed and valuable agricultural lands, causing great and irreparable damage.

The appropriate treatment is a debris dam at the mouth of the canyon, as already explained, and an improved channel extending from the spillway to a safe point on another and larger channel. Consideration has been given to the fact that the desilted water thus turned into the larger channel might intensify erosion in it below the junction point. This probably would not happen because, for the proposed locations, the silt load now carried in the larger channel is great enough so that dilution by desilted water from the side channel would not be important.

Design of secondary channels.—Channel improvement will be of two types. The first type will make use of check dams or channel drops such as are used in irrigation and soil conservation work. These may be constructed of reinforced concrete or rubble masonry. In either case the hydraulic design will be the same, and availability and cost will determine the choice of materials. The channel shape between drops will be of such a section that the banks will be stable and easily vegetated. The slope will be such that the velocity will be nonerosive and so that the earth bottom and sides will permit a maximum of percolation into the ground water without impairment of proper carrying capacity and stability.

The second method, which will be used for channel control in special situations, is the lining of the channel with reinforced concrete or rubble masonry or some other resistant material. Such construction is expensive, but there are places where it is the only practical method of control. All channel construction will be in accordance with approved standards of design, material, and workmanship, and each channel will be carefully designed to meet the specific requirements of capacity, slope, location, and rights-of-way.

High hazard agricultural areas.—The agricultural areas which depend upon debris basis and channel improvement as prerequisite to improved land use are defined as "high debris hazard agricultural areas," and make up about 10 percent of the total agricultural area to be treated. The total cost of treatment for such areas includes the cost of associated debris basins and the channels as well as the cost of the improved land use measures on the land itself. The total benefits

include the elimination of probable direct local damage from debris and flood flows, and the benefits resulting from reduction of run-off and erosion by treatment of the high hazard agricultural area.

The construction work proposed for these areas is at locations for which no treatment is proposed by either the United States engineers or the flood-control district, or where it constitutes only a very minor terminal part of their much larger program. Otherwise, it does not duplicate any work now existing, now under way, or now proposed by the Army or the flood-control district. The construction work proposed is purely in the interest of agricultural treatment of the adjacent land and does not constitute part of the system of downstream drainage control sponsored by the other agencies.

In instances where there might have been some question on this point, and where there was a possibility that the Army or the district might do the work now or eventually, the item has been eliminated or very greatly reduced to include only those parts which the other agencies would not undertake for a long time, if at all.

Twenty-three dams will be constructed in the high-hazard areas, at an average cost of $10,000 each. About 30 stretches of channel, varying in length up to 4 miles, will be improved. Table 9 shows distribution of costs for this type of construction work.

TABLE 9.—*Distribution of costs of debris basins and channel improvements*

Type of improvement	Flood control funds	Local funds	Total
Channels	$244,945	$267,705	$512,650
Dams	110,300	120,300	230,600
Total	355,245	388,005	743,250

ANALYSIS OF COSTS AND BENEFITS

The statute under which it is proposed to institute an upstream flood-control program on the Los Angeles watershed specifies that the total benefits from a program, to whomsoever they accrue, must exceed the total costs. In order to analyze the physical elements of costs and benefits it was necessary to break the program down into specific measures applied on relatively homogeneous parts of the watershed. This necessary break-down of the physical program into measures analyzed not for the watershed as a whole, but for relatively well-defined homogeneous parts of the watershed, sets the necessary pattern of economic analysis—the basis for calculating both costs and benefits of the program.

SIX CLASSES OF REMEDIAL MEASURES

The entire recommended program was divided into six distinctive types of remedial measures, as follows:

1. Fire control, including fire-truck roads, tank trucks, crew stations, fire breaks, and communications.
2. Cover improvement, including direct seeding in bare areas, areas of depleted cover, and newly burned areas.

3. Road improvement, including improved drainage and slope stabilization by engineering works and planting.
4. Mountain channel improvement, including the construction of barriers, revetments, deflectors, channel clearing, and occasional channel changes.
5. Farm land improvement and treatment—
   A. Farm-land treatment on alluvial fans and dependent on debris basins.
   B. Farm-land treatment not on alluvial fans and not dependent on debris basins.
6. Debris basins and minor channel improvements.

Break-Down of Watershed Into Flood-Source Areas

For purposes of casting up amounts of work and materials required to install the recommended measures, and for purposes of appraising the physical effects of these measures, the watershed was divided into nine flood-source areas; and two of these, for purposes of further analyses, were broken down into subareas. In each case a flood-source area was determined by the existence of a major downstream control structure such as a reservoir where total silt movement could be measured, or by natural drainage systems, or land use and run-off characteristics requiring a fairly distinct and homogeneous combination of measures. Separate analyses of costs and benefits accordingly were made for each of the above-listed six measures (except fire control) in each of the flood-source areas or subareas shown in the map herewith attached.

In the case of fire control a unit of sound physical operation is considered much larger than any one of the flood-source areas and the economic analysis of costs and benefits of this measure were of practical significance only as applied to the entire mountain area of the watershed.

Methods of Calculating and Using Cost and Benefit Estimates

Basis of cost estimates.—Costs were based on force-account wages and standards of efficiency. Costs shown in the analysis of this report include all costs of labor, material, supervision and other overhead, and in some cases, necessary rights-of-way, but do not include legal and condemnation services, and do not incorporate any contingency fund. For installation costs, however, a contingency is added, and will be explained in a following paragraph. Costs were calculated separately for installation and for maintenance, also separately for flood-control funds and other funds.

Basis of benefit estimates.—An attempt was made to include all benefits of each remedial measure for a 50-year-service period, regardless of who is to receive the benefit. Estimated unit values of each kind of benefit were applied to estimated physical quantities of benefits resulting from a given measure to obtain the total monetary value of

its benefits. The benefits for which separate estimates of value were calculated are as follows:

Type of benefit and value [1] *during period of 50 years*

1. Reduction in flood damage from impact and of water and debris from inundation	$15, 671, 872
2. Reduction of deposition in reservoirs and debris basins	5, 099, 105
3. Reduction of deposition on roads and streets	179, 384
4. Reduction of deposition on city and residential property	460, 628
5. Reduction of deposition on agricultural land	254, 870
6. Reduction of deposition in Long Beach Harbor and Bay	222, 810
Total benefits from reducing flood damages	21, 888, 669
7. Water conservation	1, 207, 409
8. Soil-conservation benefits from land treatment	15, 911, 276
9. Reduction in property loss by fire	1, 349, 450
10. Reduction in road-maintenance costs	711, 764
11. Reduction in fire-suppression costs	228, 300
12. Protection and extension of mountain recreational values	735, 994
Total	42, 032, 862

[1] Value of future benefits discounted to the present time at 3 percent interest.

Besides the above list, for which separate calculations of benefits were made, other benefits will accrue from the program for which no monetary value estimates were made. Some of these are: Reduced hazard to life and to the security of people on the watershed; reduced peak flow of floods, and a consequent added safety factor for downstream flood-control structures; increases in available soil moisture on agricultural lands.

Period of the program.—It is contemplated that most of the installation of the recommended program will be completed within 5 years and that all of it will be completed within 10 years. Benefits from, and the operation, maintenance, and replacement of, the program are calculated only for 50 years after installation of the various measures is complete. This means that some of the benefits and costs of measures not installed until the eighth year of the program will extend to the fifty-eighth year of the program, but only for 50 years after the specific measure is installed. The 50-year period was selected as a reasonable base period for the calculation of benefits and costs. Obviously, it is contemplated that all measures will be maintained intact at the expiration of the 50 years, and that the program will continue indefinitely thereafter.

Comparison of benefits and costs.—Benefits are distributed fairly uniformly over a 50-year period after the measures are installed. On the other hand, a large portion of the costs of measures are concentrated in the early years of the program. Values of costs and benefits of the program, therefore, must include interest on invested capital and discount on deferred benefits. If costs were equally distributed each year of the life of the program, and if benefits likewise were equally distributed, interest on the invested capital could be counted as a part of the cost, and an average annual cost could be compared directly with average annual benefits. But yearly costs and benefits will accrue unevenly throughout the 50 years of the program. Hence, both costs and benefits accruing in variable amounts for each year of the program had to be discounted back to a present value in order to make it possible to compare them accurately.

For example: A benefit of $100 to be received 50 years from today, when discounted back to a present value at a 3-percent compound rate, is worth only $22.81. Similarly, if the program calls for $100 of expenditure of costs 50 years from today, $22.81 of present value set aside today and drawing 3 percent compound interest will be worth the required $100 of costs 50 years hence.

The total present value of all benefits for each recommended measure within each flood-source area was expressed as a ratio of the total costs in the area. This ratio of benefits to costs is expressed throughout the report in terms of dollars of benefits per dollar of costs. No measure was recommended that did not yield more than $1 of benefit per dollar of cost.

Ratios of benefits to costs.—A summary of all costs and benefits and the ratios of benefits to costs of the recommended measures by flood-source areas or subareas is shown in table 10. As stated previously, the ratio of benefits to costs of fire control is significant as a justification for the measure only when calculated for the whole watershed, since a flood-source area is not sufficiently large to form a sound unit of physical administration of fire control. For the watershed as a whole, fire control yields $1.12 of benefit for each dollar of cost. Mountain cover improvement is especially well justified. Returns from it vary from a minimum of $1.13 of benefit per dollar of costs in area No. 2 to a maximum of $6.68 in area No. 8, with an average of $3.57 for all areas.

The work on major roads, which is recommended in 7 out of 11 areas, is even more remunerative per dollar of costs than is cover improvement. This work yields benefits varying from a minimum of $1.66 per dollar of costs to a maximum of $8.63 with an average of $4.76 for all areas. Minor road improvement on the whole, with an average of $1.97 benefits per dollar of cost, is a highly necessary and remunerative part of the recommended program. Mountain channel improvement is recommended in four areas, with average returns of $1.88 of benefit per dollar of cost, and minimum and maximum returns of respectively $1.15 and $2.09 per dollar of expenditure.

Farm land treatment in valley portion of the watershed falls into two classes of areas: Those areas subjected to high hazard from debris movement out of small frontal canyons and areas not subject to such hazard. In the high hazard areas agricultural lands cannot safely be improved without first protecting them from the hazard of debris debouching from the canyons. The benefits from recommended debris basins and channels in these high-hazard areas cannot be separated from the benefits from farm land work on the areas. Hence, in economic analysis of the high-hazard areas all measures, including debris basins and channel improvements, had to be considered as an integrated program, yielding a combination of benefits that are inseparable.

Farm land treatment is recommended in all flood-source areas except No. 3a, and 4a, which are in the mountains. Benefits vary from a minimum of $2.56 per dollar of cost in area No. 1 to a maximum of $13.34 in area No. 7, with an average of $3 for all areas combined.

Work in high hazard or alluvial fan areas, including farm land improvement as well as debris basins and improvement of secondary channels, is recommended for 7 of the 11 areas. Returns vary from a low of $1.28 worth of benefit per dollar of cost in area No. 1 to a maximum of $4.55 in area No. 7, the average for all areas being $1.49.

TABLE 10.—*Present value of costs and benefits of recommended measures for all flood source areas, Los Angeles watershed*

Flood source area No.	Items of costs or benefits	Fire control [1]	(Mountain) cover improvement	Road improvement		Mountain channel improvement	Farm land treatment valley land [2]	Treatment of alluvial fans [3]	Total all measures
				Major roads	Minor roads				
1	Costs		(4)	$89,025.00	(4)	(5)	$2,249,203.00	$1,032,327.00	$3,370,555.00
	Benefits		(4)	147,840.00	(4)	(5)	5,746,995.00	1,319,745.00	7,214,580.00
	Ratio [6]		(4)	1.66	(4)	(5)	2.56	1.28	2.14
2	Costs		$308.00	(5)	(5)	(5)	978,162.00	(5)	978,470.00
	Benefits		348.00	(5)	(5)	(5)	2,535,177.00	(5)	2,535,525.00
	Ratio [6]		1.13	(5)	(5)	(5)	2.59	(5)	2.59
3a	Costs		1,158.00	22,025.00	(4)	$425,730.00	(5)	(5)	448,913.00
	Benefits		4,306.00	154,950.00	(4)	488,334.00	(5)	(5)	647,620.00
	Ratio [6]		3.72	7.04	(4)	1.15	(5)	(5)	1.44
3b	Costs		360.00		$23,981.00	(5)	487,434.00	39,886.00	551,661.00
	Benefits		1,524.00	(5)	206,263.00	(5)	1,769,141.00	106,021.00	2,082,949.00
	Ratio [6]		4.23		8.60	(5)	3.63	2.66	3.78
4a	Costs		3,371.00	79,814.00	(4)	(4)	(5)	(5)	83,185.00
	Benefits		7,432.00	246,330.00	(4)	(4)	(5)	(5)	253,762.00
	Ratio [6]		2.20	3.09	(4)	(4)	(5)	(5)	3.05
4b	Costs		2,238.00	101,698.00	199,818.00	1,774,293.00	95,573.00	20,947.00	2,194,567.00
	Benefits		6,338.00	768,246.00	468,888.00	3,711,500.00	285,297.00	40,353.00	5,280,622.00
	Ratio [6]		2.83	7.55	2.35	2.09	2.99	1.93	2.41
5	Costs		721.00	(5)	52,861.00	(4)	151,344.00	72,017.00	276,943.00
	Benefits		1,305.00	(5)	131,790.00	(4)	590,781.00	100,320.00	824,196.00
	Ratio [6]		1.81	(5)	2.49	(4)	3.90	1.39	2.98
6	Costs		669.00	8,857.00	99,484.00	(4)	5,573.00	77,345.00	191,928.00
	Benefits		2,377.00	57,692.00	109,699.00	(4)	74,336.00	101,980.00	346,084.00
	Ratio [6]		3.55	6.51	1.10	(4)	13.34	1.32	1.80
7	Costs		61,029.00	180,879.00	112,652.00	574,736.00	113,879.00	11,983.00	1,055,158.00
	Benefits		221,272.00	797,173.00	130,350.00	1,158,407.00	599,223.00	54,539.00	2,960,964.00
	Ratio [6]		3.63	4.41	1.16	2.02	5.26	4.55	2.81
8	Costs		1,518.00	32,108.00	169,055.00	867,489.00	788,019.00	250,195.00	2,108,384.00
	Benefits		10,145.00	277,022.00	247,953.00	1,484,244.00	3,103,866.00	515,967.00	5,639,197.00
	Ratio [6]		6.68	8.63	1.47	1.71	3.94	2.06	2.67
9	Costs		(5)	(5)	(5)	(5)	764,873.00	(5)	764,873.00
	Benefits		(5)	(5)	(5)	(5)	2,220,562.00	(5)	2,220,562.00
	Ratio [6]		(5)	(5)	(5)	(5)	2.90	(5)	2.90
Total	Costs	$10,756,570.00	71,372.00	514,406.00	657,851.00	3,642,248.00	5,634,060.00	1,504,700.00	[7] 22,781,207.00
	Benefits	12,026,809.00	255,047.00	2,449,253.00	1,294,943.00	6,842,515.00	16,925,378.00	2,238,925.00	42,032,870.00
	Ratio [6]	1.12	3.57	4.76	1.97	1.88	3.00	1.49	1.85

[1] Because of the difficulty of controlling forest fires in this region, the physical and economic unit for fire control must be much larger than any one flood source area. Hence, the economic analysis of this measure and the resulting ratios are of practical significance only as regards the Los Angeles watershed as a whole.

[2] Farm land treatment on valley land not dependent on debris basin and channel protection.

[3] Alluvial fan treatment includes debris basins located at mouths of small frontal canyons above alluvial fans, associated secondary channel improvement, and agricultural land treatment (on the fans) dependent on the debris basin and channel work.

[4] Analysis made but program not economically justified. [5] This measure not required in this area. [6] Dollars of benefit per dollar of cost. [7] Including fire control.

Off-Site and On-Site Benefits

From the standpoint of expenditure of Federal flood-control funds it is important to inquire into the extent that benefits from the recommended program accrue to the property on which work is recommended (on-site or conservation benefits) and the extent to which they are received by others than the owners of the land on which the work is done (off-site or flood-control benefits). Table 11 summarizes by measures the present value of the cost of the entire program to be borne by Federal flood-control funds and other sources. It also gives total off-site and on-site benefits by measures.

The entire program will cost approximately $22,800,000 of which $7,300,000 will be drawn from Federal flood-control funds and $15,500,000 from other sources. A detailed statement of reasons for distributing costs as proposed is given in a discussion to follow. All benefits amount to $42,000,000 of present value, $22,500,000 of which are off-site benefits and the remainder on-site benefits.

Relation Between Present Value Costs and Cash Outlay

As previously stated, an accurate comparison of benefits and costs of the program can be made only by reducing costs and benefits to present value.

Cash Outlay Required for the Recommended Program

Table 13 gives a summary of the cash outlay that will be required from Federal flood-control funds for each of the six recommended measures. The total recommended cash needed to install all measures within 10 years will approximate $8,400,000.

The installation of nearly all of this work as part of an integrated program in aid of flood control is a relatively new experience in the United States, hence, installation contingencies are likely to arise. A variable contingency fund amounting to $980,000 has been set up for the different parts of the program.[1]

Table 11.—*Summary of present value of costs and benefits, and benefit-cost ratios for all measures recommended for the Los Angeles watershed improvement program*

Remedial measures	Present value of costs			Present value of benefits		Dollars of all benefits per dollar of all costs
	Costs from flood control funds	Costs from other sources	Total costs	Total offsite benefits	All benefits	
1. Fire control	$9,567,857	$1,188,713	$10,756,570	$9,969,854	$12,026,809	$1.12
2. Cover improvement	71,372	----------	71,372	191,124	255,047	3.57
3. Road improvement	764,385	407,872	1,172,257	2,560,544	3,744,196	3.19
4. Mountain channel improvement	2,517,797	1,124,451	3,642,248	6,548,687	8,842,515	1.88
5. Farm land treatment—valley land [1]	824,342	4,809,718	5,634,060	2,525,248	16,925,370	3.00
6. Treatment of alluvial fans [2]	383,375	1,121,325	1,504,700	727,779	2,238,925	1.49
All measures	14,129,128	8,652,079	22,781,207	22,523,236	42,032,862	1.85

[1] Farm-land treatment on valley land not dependent on debris basin and channel protection.

[2] Alluvial fan treatment includes debris basins located at mouths of small frontal canyons above alluvial fans, associated secondary channel improvement, and agricultural land treatment (on the fans) dependent on the debris basin and channel work.

[1] A contingent fund is requested because a large part of the construction is of a type with which experience in this country has been very limited. It is proposed for use only in such amounts as will not raise the cost of any measure above the value of its benefits.

But economic analysis requires also a budgetary presentation of costs—i. e., the amount of cash outlay that will be needed each year of the program, where these funds are to come from, and a statement of the considerations that guided the apportionment of the funds between various sources. Table 12 shows the relation between the costs of the recommended measures in terms of present values and cash outlays:

TABLE 12.—*Costs of the recommended program in terms of present value compared with costs in terms of cash outlay by sources of funds*

Form of value of program	Source of expenditure for entire recommended program		
	Federal flood-control funds	Other sources of funds	Total of all costs
Present value	[1] $14,129,128	$8,652,079	[1] $22,781,207
Cash outlay	[1] 20,725,505	14,474,664	[1] 35,200,169

[1] Excludes contingency fund of $980,000.

TABULAR SUMMARY OF PROGRAM

TABLE 13.—*Cash outlay required for installation of recommended measures from Federal flood-control funds, Los Angeles River watershed*

	Cost	Contingent [1]	Total
1. Fire control, including fire-truck roads, tank trucks, crew stations, firebreaks, and communications	$2,888,751	$309,000	$3,197,751
2. Cover improvement, including direct seeding in bare areas, areas of depleted cover, and burned areas	64,420	10,000	74,420
3. Road improvement, including improved drainage and slope stabilization by engineering works and planting	673,844	123,000	796,844
4. Mountain-channel improvement, including the construction of barriers, revetments and deflectors, channel clearing and occasional channel changes	2,425,555	443,000	2,868,555
5. Farm land improvement and treatment—			
(*a*) On alluvial fans, dependent on debris basins $98,846			
(*b*) Not on alluvial fans, not dependent on debris basins 892,974			
	991,820	62,240	1,054,060
6. Debris basins and improvement of minor channels	355,245	32,760	388,005
Total	7,399,635	980,000	8,379,635

[1] Contingent fund is 13.2 percent of total cost for installation.

The conversion of this cash outlay into terms of present value at 3 percent compound interest shows a present value under cash outlay of approximately $6,500,000 for flood-control funds. This reduction is from approximately $20,725,000 to $14,125,000. Most of the needed Federal funds for the first 5 years will be for installation of measures. (See table 15.)

Since funds from other sources will be used largely for operation, maintenance, and replacement, they will be used throughout the entire 50-year life of the program, and will be required mostly in the future. Hence, the time discount on them is heavier than on Federal funds. The cash outlay when reduced to present value drops from a total of nearly $14,500,000 to slightly over $8,650,000.

Cash Outlay Required From All Recommended Sources

Table 14 shows the total cash requirements from all recommended sources of funds during the first 50 years of the program. Besides the $8,400,000 required from Federal flood-control funds to install the program, State and local sources will be expected to supply approximately $1,900,000, farmers $1,120,000, and other private sources $32,000 out of the total estimated requirement of approximately $11,400,000 for installation.

For operation, maintenance, and replacement it is recommended that all Federal costs be met from Federal flood-control funds. This will require an average of $307,963 annually. State and local agencies will furnish $50,645 annually, and farmers and other individuals $178,363 to maintain and continue the farm-land measures and practices.

Table 14.—*Summary of all cash outlays recommended for the installation and the 50-year operation, maintenance, and replacement of a watershed-improvement program on the Los Angeles River*

Type of costs	Federal flood control	State and local	Farmer	Total
Installation costs	$7,399,635	$1,884,775	$1,120,058	$11,384,468
Contingent fund	980,000			
Total	8,379,635			
Operation, maintenance, and replacement costs for 50 years	13,325,870	2,552,711	8,917,123	24,795,704
Total	21,705,505	4,437,486	10,037,181	36,180,172

Apportionment of Cash Outlays as to Sources

Much of fire control, mountain road improvement, cover improvement, and mountain channel improvement will be done on Federal lands within the Angeles National Forest. For this reason it is recommended that payment for all installation work of the above measure on Federal lands be made out of Federal flood-control funds. This accounts for the relatively heavy apportionment of installation costs of these measures to this source (table 15). Installation outlays for fire control, mountain channel improvement, and debris basins and minor channel improvement on alluvial fans, on non-Federal lands and road improvement on nonfederally maintained roads is to be borne equally from Federal flood-control funds and from State and local or individual sources in accordance with the ownership of the lands on which the work is to be done. In addition, it is proposed that local government agencies shall provide all right-of-way costs for work on non-Federal land in addition to half the installation cost.

In the farm-land improvement program the Federal Government will provide technical lay-out work, materials, and loan of equipment averaging in value about $5 an acre. The total expense to the Government of farm-land improvement measures, including everything financed from flood-control funds except debris basins and channel improvements, will be approximately equal to the expenditures required of the owners of the land.

As is indicated in table 15, fire-control measures on Federal land are to be maintained by the use of Federal flood-control funds. On private or State and local government land, local governmental jurisdictions are to carry expenses of fire-control operation, maintenance, and replacement. Farm land owners are expected to carry all future operation and maintenance cost of the farm land improvement programs. Debris basins are planned in such manner that they will require replacement at approximately 40 percent of their original installation cost around 25 years after their original installation. As the local governments are expected to maintain these basins and their associated channels, it is planned that these local governments will likewise provide the funds necessary for replacement each 25 years of their use.

Over a period of 50 years there will be a Federal expenditure of $21,700,000, an expenditure of $10,000,000 by farmers, and an expenditure by State and local governments of $4,400,000 in the watershed improvement program. The contribution of the Federal Government to flood control in the Los Angeles area through its protection and administration of the mountain areas, has been and will continue to be large. The benefits of this large Federal expenditure accrue largely to the people of the Los Angeles area. Because of the large share of the cost of mountain land protection already borne by the Federal Government, it seems reasonable to ask the benefiting locality, through its appropriate governmental agencies, to bear half the cost of new installation on non-Federal roads and property, to obtain rights-of-way, and to maintain structures.

It is recognized that these local jurisdictions also have already expended considerable sums on works in the interest of flood control and will continue to do so. It is further recognized that they have planned structures to aid in flood control that may have prior claim on their funds over the work proposed by the Department of Agriculture. Therefore, in the interest of obtaining early cooperation on the measures on non-Federal land needed to complete a well-rounded watershed improvement program, and in recognition of a certain measure of national responsibility even for problems largely local in character, it is proposed that the Federal Government offer local jurisdictions half the cost of installing measures on non-Federal lands. The details of a plan of cooperation between the national and local or State jurisdictions on these measures would be subject to negotiation after the local or State agencies have satisfied themselves of the desirability of cooperation.

It is expected that farmers benefiting from measures applied to their land will bear the cost of such measures in an amount at least proportional to the benefits they receive.

TABLE 15.—*Total cash outlay*[1] *required for installation and 50-year operation, maintenance, and replacement of recommended measures by sources of funds, Los Angeles River watershed*

A. CASH OUTLAY FOR INSTALLATION

Measures	Total cost to Federal flood control	Total non-Federal cost		Total cost
		State and local governments	Farmers and other individuals	
1. Fire control	$3,197,751	[2] $252,570	0	$3,450,321
2. Cover improvement	74,420	0	0	74,420
3. Road improvement	796,844	[3] 247,755	[4] $31,701	1,076,300
4. Mountain channel improvement	2,868,555	996,445	0	3,835,000
5. Farm-land improvement and treatment:				
(*a*) On alluvial fans	105,946	0	113,466	219,412
(*b*) Not on alluvial fans	948,114	0	1,006,592	1,954,706
Total	1,054,060		1,120,058	2,174,118
6. Debris basins and minor channel improvement	388,005	[2] 388,005	0	776,010
Total	8,379,635	1,884,775	1,151,759	11,416,169

B. CASH OUTLAY FOR OPERATION, MAINTENANCE, AND REPLACEMENT

1. Fire control	$13,011,095	$1,823,565	0	$14,834,660
2. Cover improvement	17,680	0	0	17,680
3. Road improvement	117,845	148,150	$18,980	284,975
4. Mountain channel improvement	179,250	248,750	0	428,000
5. Farm-land improvement and treatment:				
(*a*) On alluvial fans			886,789	886,789
(*b*) Not on alluvial fans			8,011,354	8,011,354
Total			8,898,143	8,898,143
6. Debris basins and minor channel improvement	0	332,243	0	332,243
Total	13,325,870	2,552,708	8,917,123	24,795,701

[1] The term "cash outlay" as used here includes the value of labor contributed by farmers and others.
[2] Half of the cost of installation on non-Federal land plus right-of-way cost.
[3] Half of cost of installation on roads maintained by the State, county, and city.
[4] Half of the cost of installation on private roads.

SUPPLEMENTAL AIDS TO THE DEPARTMENT OF AGRICULTURE PROGRAM

PUBLIC ACQUISITION OF PRIVATE LANDS AS A MEASURE OF FIRE PREVENTION

The private ownership of certain lands in hazardous areas within or adjacent to the Angeles National Forest in the mountain section of the Los Angeles watershed contributes seriously to the flood problem. Many of these holdings have been or are potentially sources of fire and hence of flood damage through erosion and debris flows. They also prevent effective closure of the surrounding fire-hazard areas. Some of the lands, notwithstanding their steep rough character, have been or are still cultivated and contribute to flood damage by run-off and erosion from the sloping fields, while private roads add further to the flood damage from erosion debris. Approximately 22 percent of all forest fires in the watershed during the period 1931 to 1938 were started by debris burning and by other activities around buildings on these private lands. Due to the position of these lands, the spread of fire from them to adjacent public lands is a constant

threat to the entire watershed and to the proposed program for its improvement. The distribution of private lands within the forest and in the critical zone adjacent to the southerly boundary are shown on the attached map.

The most critical of these lands are those situated along the southerly boundary of the forest and along canyon bottoms in the interior. In many places the present boundary of the national forest is well up on the southerly slopes of the mountains with privately owned lands on both sides of the line. Fires starting on these lands often sweep uphill so rapidly that control is practically impossible until they reach the summit of a ridge. By the time the ridge top is reached the fire perimeter may be so large that lateral spread along the slopes proceeds more rapidly than control. In the interior, fires started at the foot of a slope expand in similar fashion. During bad fire weather the chances are high that such fires will develop into major conflagrations before they can be stopped.

In recent years there has been a great increase in residential and small institutional construction (sanitaria and private schools) on the lands along the forest boundary. This concentration of people along the "contact" line between Federal and private lands on the high-hazard south slopes greatly increases the risk of fire. There is no indication that use of the zoning authority by the local government will halt this expansion, and experience has shown that regulation through town and county ordinances is inadequate to handle the fire situation. It is not practical to surround the private lands with cleared firebreaks nor to build roads enough around them to provide adequate fire protection.

These lands are steep and rough watershed lands; they are under private occupancy and are definitely submarginal for agriculture. Most of them are chaparral covered, although some are suited to tree growth. So long as these lands are not managed in the interest of the public and constitute public nuisances, the logical disposition of these lands is their acquisition and retention in public ownership in the interest of watershed protection and in aid of flood control. Then too, the location of these lands is such that the detritus from them when the cover has been disturbed, threatens communication, power, and transportation lines, and industries many of which are of vital concern to national welfare.

Approximately 14,000 acres of privately owned land inside the Angeles National Forest and 9,000 acres in the high fire-hazard zone just outside the south boundary of the forest are included in these privately-owned problem areas within the Los Angeles River watershed. Of the total 23,000 acres, by far the greater part is in the critical class which should definitely be in public ownership. The maintenance of a cover on these lands is a public responsibility as the owner of them has no interest in the cover.

An act (June 11, 1940) authorizes use of a portion of the Angeles National Forest receipts for purchase of private lands within the national forest "to facilitate the control of soil erosion and/or flood damage." The small amount available from this source annually would permit, over a period of years, the acquisition of only the most urgently needed lands, since, because of the proximity of these lands to urban development, the cost of acquisition will be high. However, the need for public ownership of these critical watershed lands, not

only within the national forest but those immediately adjacent to it, is so great and so urgent that this purchase program should not be delayed. In order to speed up the program and to extend the boundaries of the Angeles Forest to include these critical contiguous lands a special authorization from the Congress is necessary. This matter is being called to the attention of the National Forest Reservation Commission.

Approximately 825 acres of municipally owned watershed lands in the national forest are administered in harmony with flood-control objectives and their acquisition is not recommended.

Zoning Against Occupancy of Flood-Hazard Areas

Zoning against further occupancy of flood-hazard areas would seem to offer some possibility of reduction of future flood damages, particularly in view of the expected increase in population in the watershed. However, no legislation exists for effective regulation of the existing situation in the Los Angeles watershed and it is somewhat doubtful if it could be readily invoked in this watershed, even if provided for by law. Much of the flood-hazard area has already been subdivided for future occupancy and is therefore past the stage where zoning could be made effective. Because of the recent rapid expansion of settlement it would be very difficult to bring sufficient pressure to bear to initiate zoning regulations.

One step in this direction, however, is the legal requirement that official subdivision plats filed in the county records must bear a statement by the flood-control committee of the Regional Planning Commission of Los Angeles County covering the nature of the existing flood hazard in the area covered. To some degree this prevents settlement in the hazard areas but it is not required that the buyer be informed of the danger, and thus the procedure is somewhat ineffective. In spite of its apparent limitations in this watershed, zoning is being further investigated by the Bureau of Agricultural Economics to determine the extent to which it might be made effective.

Restriction in granting of loans to private interests offers some measure of reduction in future flood damages. The Federal Housing Administration, for example, consults the Los Angeles County flood-control district regarding flood hazards in an area before approving the area for Federal Housing Administration loans. The Los Angeles County flood-control district operates a free flood-hazard advisory service which is consulted by finance companies and individuals. A more general use of this service would do much to reduce future flood damage. This should be encouraged. At present not much use is being made of information on the location of flood-hazard areas. Effort should be directed toward making this information more readily available to the local public. Widespread circulation of maps showing flood-hazard zones would be a step in the right direction.

CONTENTS OF APPENDIX

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